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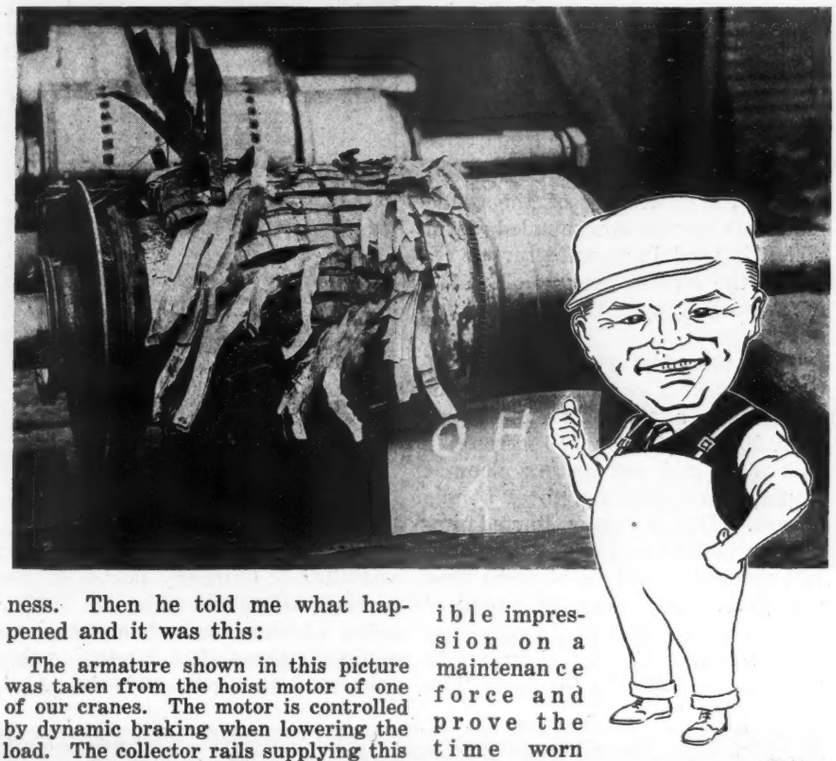
Here's What May Happen When You Get Careless

In Inspections and Adjustments of Control Devices and Ignore Precautions Against Natural Wear and Tear



I HAVE just returned from a trip through some large industrial works where I always feel at home with the hum of machines all around and have a chance to chat with men who talk about their work with an intimate knowledge of it and the pride of doing something of interest to a visitor who used to be one of them. Of the things I saw and the things I was told there will be more later in articles soon to appear, for every man I visited had a method or a practical scheme that represents hours of thought and has cured some particular trouble-making condition.

But in one plant I saw this picture of an exploded armature that shows as nothing else can the thorns that prick the pride of the superintendent who works nights and days to prevent such troubles and is always urging his men to follow the precautions of inspection and maintenance that will eliminate them. At first he did not want me to take the picture away, but I convinced him that it was no reflection on him that this one accident had occurred over a long period of time and that it would enable me to call the attention of others to the fruits of carelessness. Then he told me what happened and it was this:

The armature shown in this picture was taken from the hoist motor of one of our cranes. The motor is controlled by dynamic braking when lowering the load. The collector rails supplying this motor are trolley wires instead of the more modern angle-iron or bar-type collector rails. At the time this armature failed, the motor was lowering a very heavy load. Just when the hook speed became normal one of the trolley wires in the dynamic circuit broke and the armature ran away. The shoe brake should have prevented the runaway, but it was adjusted so loosely that it was ineffective.

In this particular plant inspection requirements are rigidly outlined and every man knows that failure to follow them calls for immediate dismissal. But in this case the inspector became careless and took one of those chances that are never safe to men or machines. The blame was easily placed and the prevention so simple with thorough inspection and proper adjustments that the same accident will not happen again unless similar carelessness and indifference to inspection requirements creep in. And this is hardly probable for a long time, as the actual results of an accident like this leave an indelible impression on a maintenance force and prove the time worn saying about an ounce of prevention and the pound of cure.

Let me say then to you men in charge of inspection—Follow the instructions of your boss and discuss them afterwards. Remember that he cannot do his job and yours, too, and that you owe it to yourself, your family and the company that pays your salary to be as careful, thorough and persistent in preventing troubles as you are in correcting them. Some day when you are the boss you will expect this of your men and the best way that I know to prove that you have the ability for a better job is to help your present boss to prevent accidents, avoid breakdowns and make improvements which will save the trouble and money that he knows and you know will result.

Practical Pete

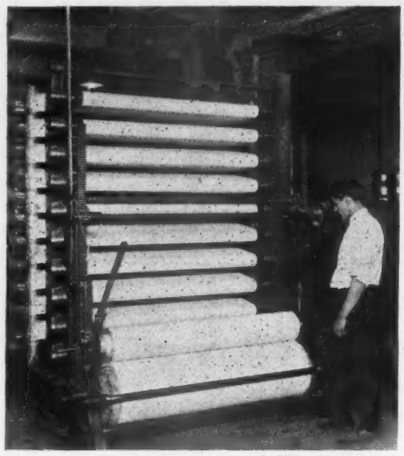
A Glimpse Into

The Goodyear Tire and Rubber Company

Where 32,000 rubber tires, 37,000 tubes and 300,000 pairs of rubber heels, in addition to large quantities of rubber belting, hose, packing and many other rubber products, are produced daily in their extensive plants.

LAST YEAR at the Akron, Ohio, plant of the Goodyear Tire and Rubber Company 12,000,000 kilowatt-hours of electrical energy were generated and used in the manufacture of numerous rubber products. In addition, the Los Angeles, Calif., plant used about 10,000 horsepower and the Canadian plant 5,000 horsepower daily. The milling of the rubber in the processing of the crude material to the compounded form which is used in manufacturing requires the largest amount of power of any other operation in this industry.

The manufacturing plants of the Goodyear Tire and Rubber Company have a total floor space of 7,250,000 sq. ft., or 166 acres. If this were laid out on one floor it would be over one-fourth of a mile square. This company started production in 1898 and by the year 1902 had reached an output of 5,000 tires per year. Last year, it produced 9,250,000 tires and up to date, has produced over 60,000,000 tires. In addition, in 1923 the Goodyear Tire and Rubber Company placed on the market 81,000,000 pairs of rubber heels, which is more than enough to equip the shoes of each adult in this country with a pair of heels. Also, it produced 8,000,000 ft. of belting, 25,000,000 ft. of hose and over 2,500,000 lb. of packing and similar products, not including molded goods. This list, however, does not include all the rubber products produced.



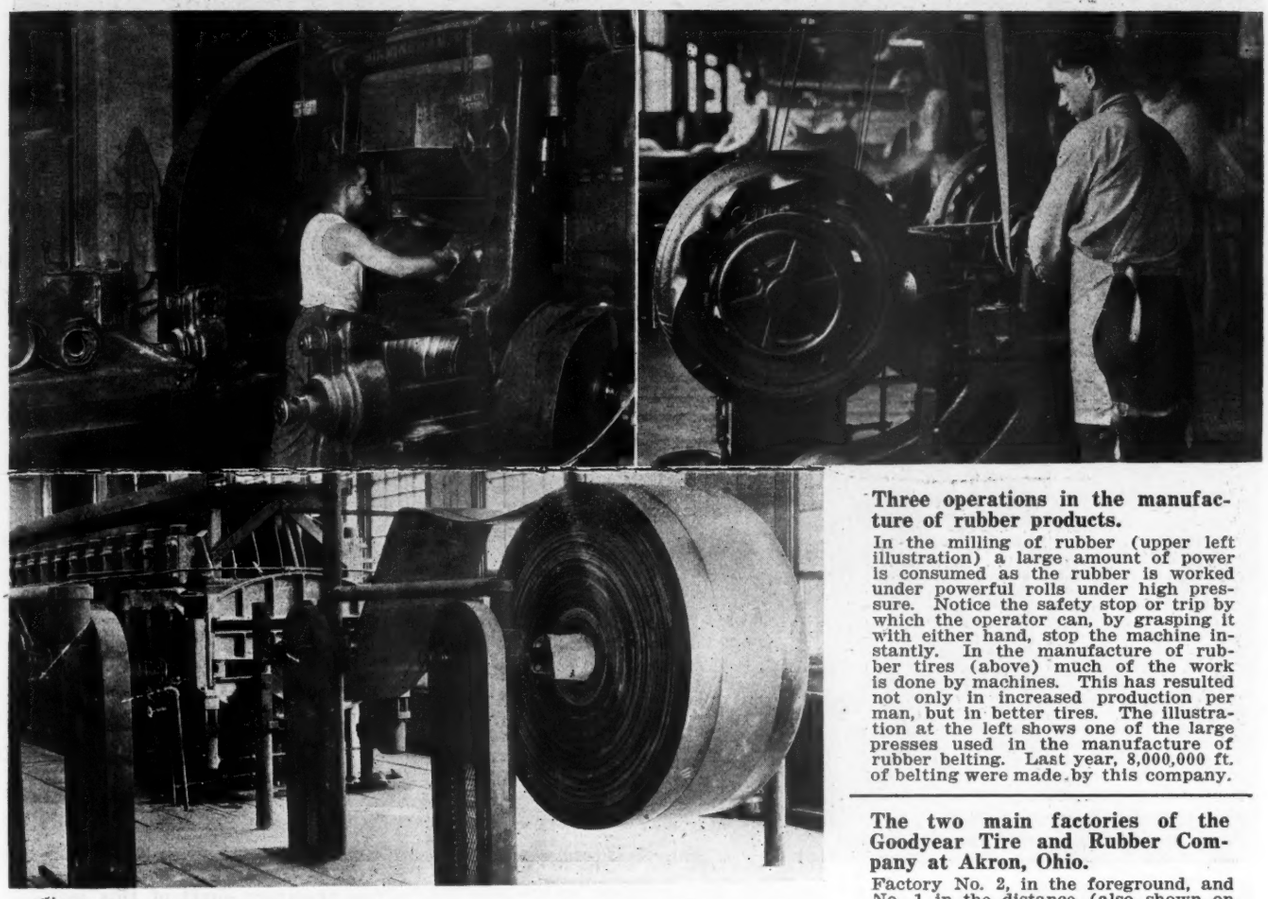
Before use the fabric must be perfectly dry.

As the fabric passes over the heated rolls it is thoroughly dried. The rubber industry uses altogether about 450,000 bales of cotton each year, of which the Goodyear Company alone uses about 75,000 bales.

The rubber industry and its growth is closely related to the rapid growth of the automobile industry. The increased demand for automobile tires has been one of the largest factors in the growth of this industry. Crude rubber is practically all imported from South America, Ceylon, Borneo and the Malay Peninsula. It is made from a milk or gum obtained from a tree. In 1923, about 305,000 tons of crude rubber, or 80 per cent of the entire world's consumption were used in the United

Plant No. 1 at Akron, Ohio, and the Goodyear Cotton Mills at Goodyear, Conn.

The Goodyear Tire and Rubber Company, not only has its own factories but also has its own cotton mills in Connecticut and cotton plantations in Arizona. The payroll of this company was over $30,000,000 in 1923. The total output in 1923 of all the Goodyear plants was 237,000,000 lb. of rubber products.



Three operations in the manufacture of rubber products.

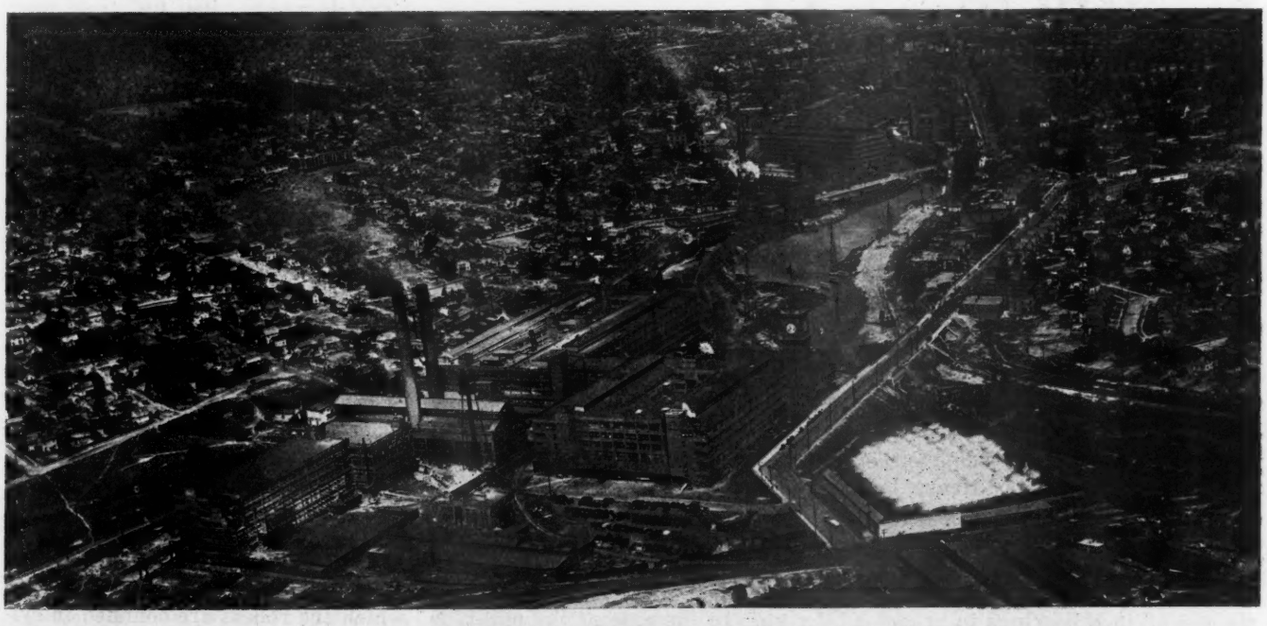
In the milling of rubber (upper left illustration) a large amount of power is consumed as the rubber is worked under powerful rolls under high pressure. Notice the safety stop or trip by which the operator can, by grasping it with either hand, stop the machine instantly. In the manufacture of rubber tires (above) much of the work is done by machines. This has resulted not only in increased production per man, but in better tires. The illustration at the left shows one of the large presses used in the manufacture of rubber belting. Last year, 8,000,000 ft. of belting were made by this company.

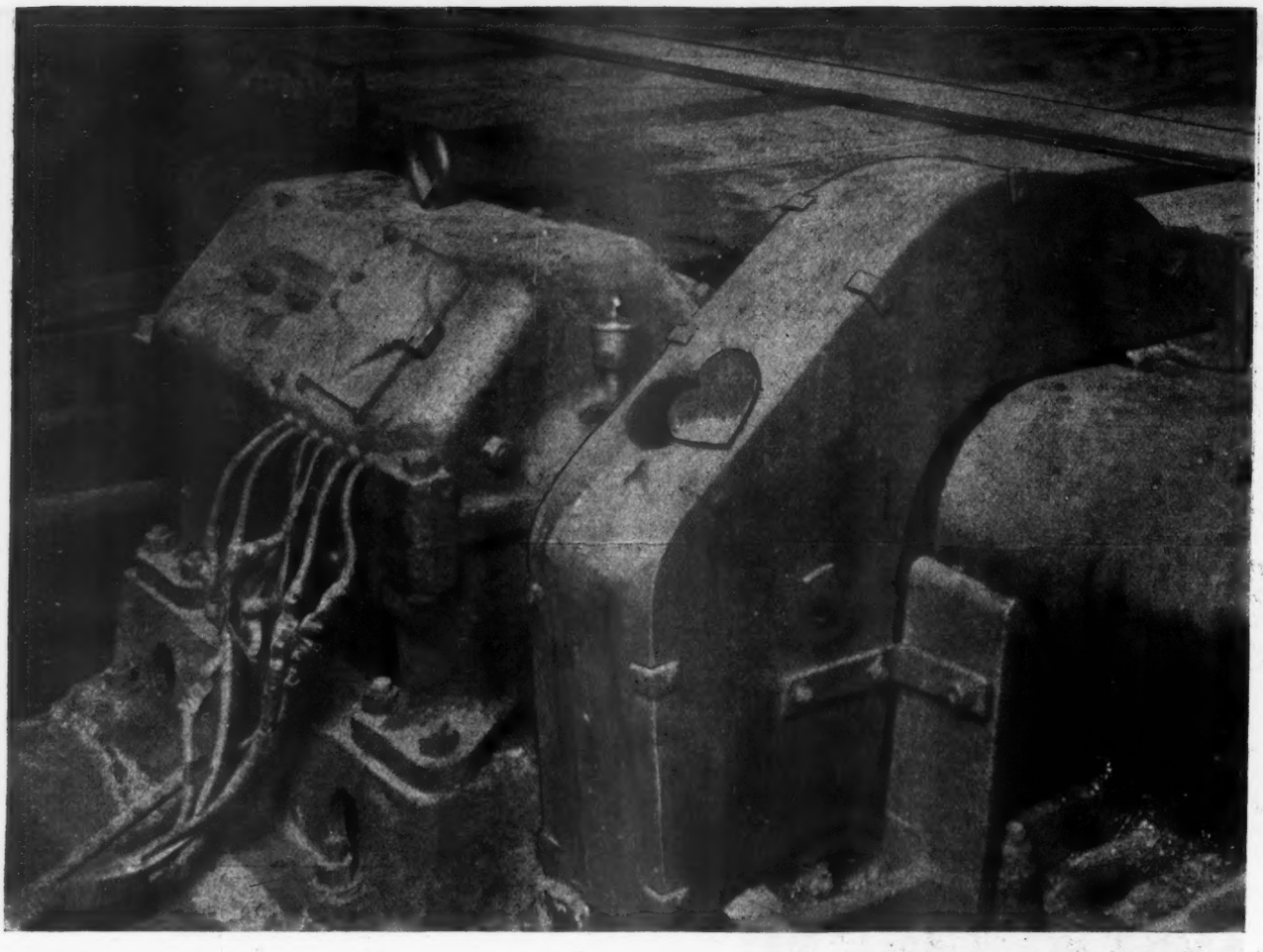
States. Of this, Goodyear consumed about 50,000 tons. In addition to the rubber large quantities of cotton are also used to form a base on which to deposit the rubber, as in tires, hose and belting. The total consumption of cotton by the rubber industries in 1923 was 450,000 bales of which Goodyear used 75,000 bales.

During the past ten years, this industry has grown to be one of the largest in (*Continued on page 210*)

The two main factories of the Goodyear Tire and Rubber Company at Akron, Ohio.

Factory No. 2, in the foreground, and No. 1 in the distance (also shown on the opposite page), are the two main factories of the Goodyear Tire and Rubber Company. In addition, other large factories are located in Los Angeles, Calif., and at Bowmanville, Ont. In the two plants shown below the machines and equipment are driven by 2,600 electric motors with a total rating of 74,157 hp., and ranging from ½- to 750-hp. rating each.





The armature shaft of this motor runs on roller bearings.

The motor drives one of the runout tables of a skelp mill. As will be noticed the table rollers are driven through bevel gears from a lineshaft, the lineshaft in turn being driven by the motor shaft through one gear reduction. This application is subjected to rapid reversal or plugging, and to the customary dirt and heat of the steel mill. The motor shown is a Crocker-Wheeler size FW, and the bearings on it are similar to those shown in the following illustrations.

Practical Operating Details of

Roller Bearing Service In Mill-Type Motors

Together with Improvements in Operation and The Results of Experience Obtained Under Severe Service Conditions in Steel Mills

By L. J. HESS

Chief Electrician, Youngstown Sheet & Tube Company, Youngstown, Ohio.

THE POSSIBILITY of adapting some form of anti-friction bearing to mill motors has long been apparent to steel mill engineers, but they have been slow to experiment with or adopt either ball or roller bearings. Heavy load shocks from reversal and plugging, added to the ever-present distrust of innovations, has retarded experiment along this line and has caused the use of such bearings to progress very slowly. In this article I shall not attempt to discuss ball bearings beyond pointing out that they have been successfully applied to various types of motors, among which the mine locomotive probably has the heaviest duty, nor treat the subject in a general way, but will tell of my experience with a particular type of roller bearing which has given very satisfactory service on slow-speed, heavy-duty, mill motors.

In the application of roller bearings to motors already in service the first problem to be solved is one of design. In the case of the mill-type motor the bearings must be so constructed that they will fit in the present frame, inasmuch as a change of frame is obviously not possible. This is a real problem for the designer. He must carefully consider the space available, the load to be carried, the effect of pinions and brake wheels, and keep constantly in mind the fact that he must use manufacturers' standard parts. He must decide which type of bearing is to be used: the spring-roller type in which the roller is in reality a very heavy spiral spring accurately ground to size on the outside; the taper solid type in which two sets of solid taper rollers in taper races oppose each other; or the cylindrical solid-roller type in which the rollers are confined in cylindrical races. The design of the

shaft also enters into the problem as it will be readily seen that any bearings of the roller type must be a snug, although not tight, fit on the shaft, for the hardened inner race must slip easily onto the shaft. There must, however, be no play or the race will soon wear its way into the shaft. Again, it is necessary that the journal be accurately machined and it is not possible to fit roller bearings on old shafts nor on new ones from the factory because grinding to size is essential. Heat treatment of shafts is also desirable in order that the surface may be harder and tougher so as to withstand the action of the race. Using a steel with 0.50 per cent of carbon, quenched in oil at a temperature of 1,500 deg. F. and drawn back to 850 deg. F., a shaft is obtained which is tough and moderately hard, with the added benefit derived from refinement of grain and improvement of the breaking strength. In case the motor manufacturer's standard shaft has the same size journal as pinion fit, it is necessary to increase this journal size 0.010 in. in order that the race may clear any slight burrs caused by pulling off pinions or brake wheels. This causes no inconvenience, for as was mentioned before, a new shaft is necessary anyway. In this particular design of bearing the question of the fit on the outside of the bearing is not so important, as it is securely clamped between the two halves of the shell. The inner fit has to be exactly right. I may say that so far as hardening of the shaft is concerned, we do not confine this to roller bearings alone. All of our shafts are hardened in the manner mentioned above. We find it is beneficial to put in a hardened shaft whether babbitt or roller bearings are used.

Our first installation of roller bearings was made on a Westinghouse series crane motor used for hoist service. These bearings were obviously an effort to adapt an automobile-type bearing to motor service. This attempt was unsuccessful, however, probably due to the lack of study of the problem involved and to the fact that the manufacturer who furnished them was at that time re-

THIS IS THE SECOND of a series of articles on bearings of the sleeve, roller and ball designs, that will give the advantages of each compared with the others from the viewpoint of meeting the wide range of service conditions encountered in industrial work. This article on roller bearings was expanded and amplified by the author from a paper which he read before the Association of Iron and Steel Electrical Engineers. INDUSTRIAL ENGINEER invites users and manufacturers to contribute their comments on the information presented in this article and in the other articles of this series. Comments relating to the improvement in bearing operation that actual service has shown, are especially invited.—EDITORS.

designing his bearings. This try-out occurred about six years ago and as it was unsuccessful was followed by a period of inaction.

This failure convinced me that a great deal of experimental work was necessary in order to develop satisfactory roller bearings for mill motors. During the full swing of the wartime rush few manufacturers of roller bearings were in a frame of mind to give time or thought to the matter. One, however, realized the possibilities and took the time to do some pioneer work. His bearing was of the cylindrical, solid-roller type and seemed well fitted for use on small motors. His engineers undertook to make the necessary designs and build the bearings. These solid-type roller bearings were applied to a Crocker-Wheeler size EW series motor driving, in tandem with a similar motor, the bridge of a 100-ton hot metal crane in a mixer building. This installation was a marked success. Previously on this drive a four-months run on babbitt bearings was considered good, while frequent armature changes, broken bands and flat spots were the rule. At the time the roller bearings were applied the commutator of the armature was badly worn and had an estimated life of three months with babbitt bearings. The winding was in such condition that the installation of a new commutator meant rewinding. After the roller bearings were installed the armature was put in service in April, 1918, and it ran for about nine months, or three times its estimated life on babbitt bearings, before the commutator started to throw bars. The armature was then rewound, a new commutator installed and except for possibly three months during which time minor electrical repairs have been made, this armature has been in continuous service. No trouble with the bearings has developed nor has any grease or oil leaked onto the commutator or windings. A re-

This is a closeup view of the other end of the motor shown in the illustration at the beginning of this article.

A grease cup is used to supply grease to the bearing, because the best of grease evaporates to some extent and the addition of a certain amount of fresh grease is of value.

cent inspection of these bearings shows that they have worn about 0.004 in., which is the ordinary tolerance for a new babbitt bearing.

The next development came in bearings suitable for Westinghouse type K motors, which the manufacturer equips with a bronze, sleeve-type bearing. A difficult problem confronted the designer in this case for obviously a roller bearing will not go in the space provided for a thin bronze-sleeve bearing. But by making a new head, which in the case of the type K motors is a comparatively small casting, it was possible to design a satisfactory bearing. These bearings were installed and have given such good service that, while they have not been in use as long as the others, we have every reason to believe they are just as good.

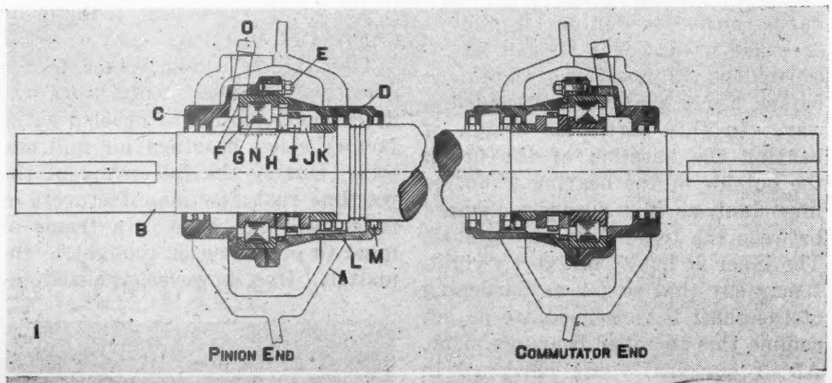
We had some difficulty in getting the first set of bearings which were sent to us into the frame, as the oil well core had slipped a little. The bearings were designed so closely that they would not go in. It was necessary for us to do some chipping but it did not take long to correct that error. The Westinghouse type K motor is clearly an example of what can be done to improve a decidedly difficult problem in motor lubrication.

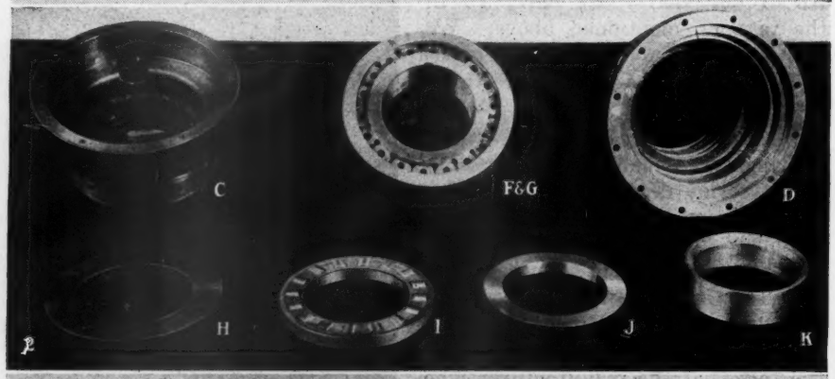
The success of these second and third applications encouraged the trial of other sizes and at present roller bearings have been developed for Crocker-Wheeler type SM, sizes CW, DW, EW, FW, and Westinghouse type K, No. 3, 4, 6 and 8 frame motors. These bearings we carry in stock and as fast as repairs to armatures necessitate new shafts and the repair record of the motor indicates the necessity of roller bearings, they are put on. There is one slight disadvantage connected with the use of these roller bearings, in that they cannot be so readily changed as the ordinary split sleeve bearing. We do not attempt to change them out in the mill; all bearings are changed and put on the armature in the shop, as we found by long experience that the other method does not pay. Likewise, when a pinion change is required, a complete armature with new pinion is changed instead. Pinions are changed only in the shop where proper facilities for making such changes are provided.

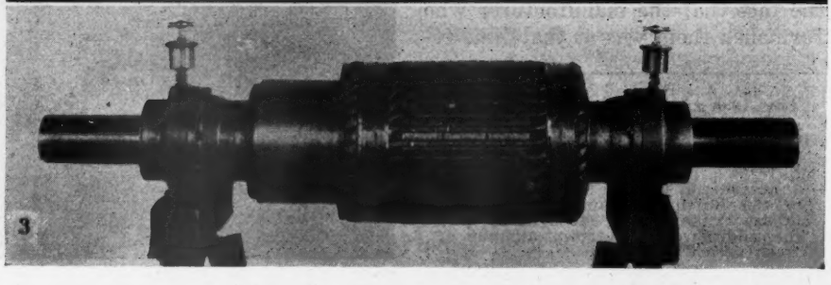
In Fig. 1, illustration 1, is shown a section of two of these bearings applied to an EW motor armature. The frame of the motor has not been altered in any way. The shaft is 4 in. in diameter for the pinion fit and 4.010 in. where the bearing fits, and is ground to size. The two malleable iron halves are held together by cap screws and clamp the outer race tightly, which serves to keep the alignment. The space between the outer and inner races is completely filled with the rollers, no spacing cage being used. The thrust collar bears against the outer race, which is slightly wider than the inner one, thereby freeing the inner race of any tendency to transmit the thrust through the rollers. Referring to Fig. 1, illustration 1, the thrust is transmitted from the shaft through sleeve *K* to collar *J*, through roller thrust *I* to collar *H*, and thence to the outer shell. The inner race is prevented from turning on the shaft by the feather key *N*, and is a snug slip fit on the shaft, allowing it to move laterally so the thrust bearing can operate, by taking the thrust around the outside of the rollers. Recent experiments lead us to believe that thrust bearings will not be necessary in any size motor unless some abnormal condition is encountered. The thrust bearing locks the armature in one position so that it is not free to oscillate and find its magnetic center. It is better to provide for a floating action of the armature by having the outer race made slightly wider than the inner race. Felt rings prevent the grease from leaving the bearing and any grease which reaches the trap is sent back through a drain channel to the bearing. The bearing is filled with grease through a pipe to which a grease cup is attached. At the commutator end it will be noticed that

Fig. 1—Roller bearing applied to a Crocker-Wheeler type SM, size EW motor.

In the cross section of the bearing shown in illustration (1) the items are lettered to correspond with the parts shown in illustration (2). *A* is the frame of the motor; *B* is the shaft; *C* and *D* are held together by the cap screws *E* and clamp the outer race *F*; *G* are the rollers; *H* is the thrust collar which bears against the outer race. The thrust is transmitted from the shaft through the sleeve *K*, to collar *J*, through roller thrust *I*, to collar *H*, and thence to the outer shell. In illustration (3) the bearings are shown assembled on the armature shaft as it would leave the repair shop.







the inner felt rings do not bear on the shaft but instead bear on an extension of the armature quill, which is not shown. These bearings are duplicates and can be assembled end for end. In Fig. 1, illustration 2, are shown the parts of the bearing lettered to correspond to the cross section of illustration 1. In Fig. 1, illustration 3, is shown an EW armature assembled complete with bearings ready to go on the mill spare rack.

In Fig. 2 is shown a section of a type K, No. 8 frame Westinghouse motor armature. The shell, *A*, instead of being a bearing shell is the head of the motor and is held to the motor by cap screws exactly as the head which is furnished by the manufacturer. The other parts of the bearing are lettered the same as in Fig. 1 and can be readily identified. This bearing is also furnished with a padded housing to carry a brake. Except for this feature these bearings are interchangeable end for end. In Fig. 2, illustration 2, are shown the parts of the bearing lettered to correspond with the cross section in illustration 1. In illustration 3 is shown the No. 8 type K armature assembled complete with the bearings. In another illustration are shown the parts of the bearing for the No. 3 type K armature. This bearing has no thrust collar or bearing, inasmuch as the rollers and races are themselves ample to take care of the thrust on the small size motor in which they are used.

The lubrication of the bearings is a very simple matter as practically no grease escapes. Once a week the grease cup is given one turn. The grease used is No. 3 Keystone or its equivalent. It is important to see that a good quality of grease is used for lubrication. A semi-fluid grease has been found best. Some trouble has been experienced in that subsequent shipments of grease of supposedly the same quality have not had the same characteristics. This trouble has been overcome by having roller bearing grease tested before use. Any grease showing the presence of fibrous material, filler or talc is promptly rejected as it will ruin the bearings. A temperature test is applied to see whether the grease maintains the same consistency throughout the temperature range that a roller bearing is normally expected to work at. One time a set of bearings failed because one of the men filled the bearing with cheap grease which had in it a large percentage of filler of a non-lubricating nature. The bearing soon started to heat and the thrust was

Eight Advantages of Roller Bearings

THREE HUNDRED sets of roller bearings are now in operation and practically no failures have resulted. From my experience with these roller bearings, I have found that their use offers the following advantages:

1. Electrical repairs to commutators and windings are greatly reduced because fully 50 per cent of these troubles start from oil and grease working their way onto the commutator and front V ring. With roller bearings the grease is entirely confined within the bearing shell.

2. Commutator wear is materially reduced because there is no jumping of the armature due to loose bearings, with its tendency to cause flashing and consequent flat spots. The shafts also are longer lived because the only wear on them is in the keyways.

3. The fact that the armature is held constantly in the center of the magnetic field helps to make the current distribution uniform, thereby relieving the equalizer connections of abnormal duty.

4. Broken bands due to rubbing are unknown.

5. Pinions are kept accurately in mesh and crowding of the teeth with consequent strain and vibration is eliminated.

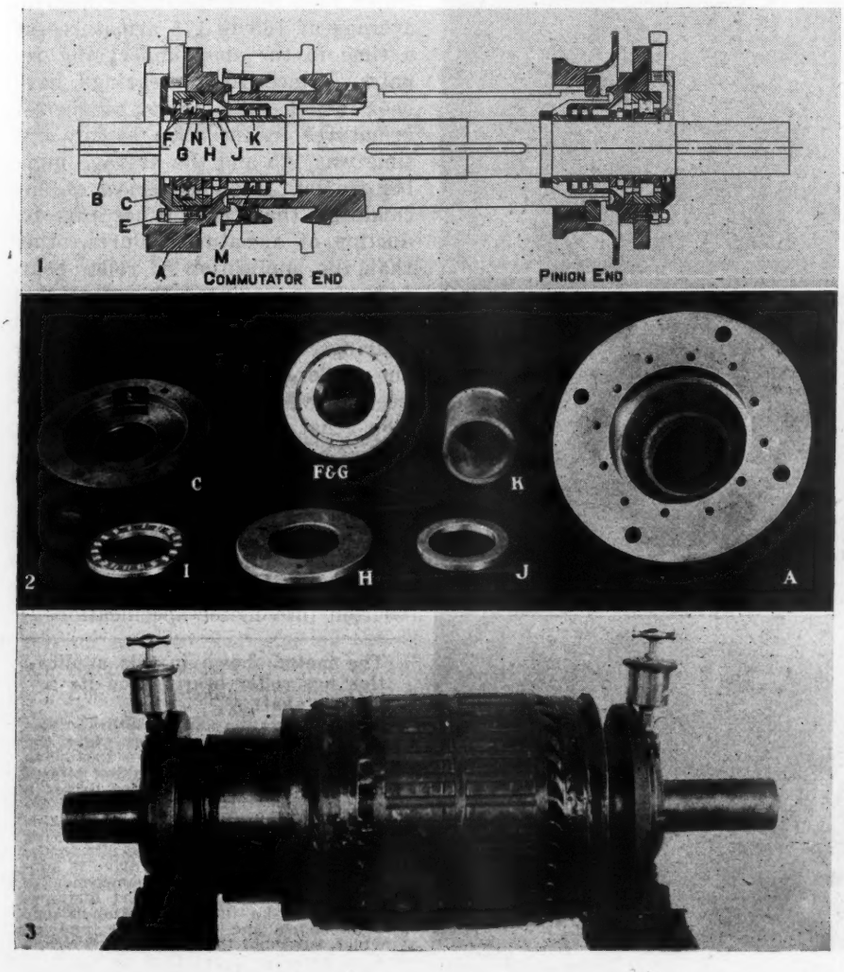
6. Expense of inspection is somewhat reduced due to better commutation and less attention required for lubrication.

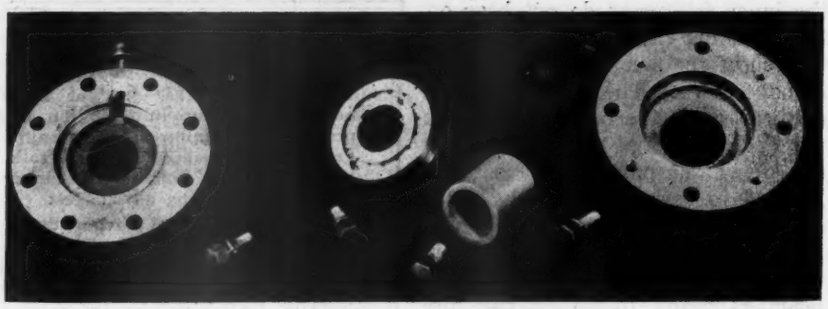
7. The cost of lubricants is reduced to an almost negligible figure as the bearings consume practically no grease.

8. Because of the reduction in repairs it follows that not only is labor and loss of time in the mills during armature changes reduced, but also the delay time charged against the electricians.

Fig. 2—This is the assembly of a roller bearing for the No. 8 type K Westinghouse motor.

In illustration (1) the sections of the bearing are lettered to correspond with the parts shown in illustration (2). *A* is the head of the motor; *B* is the shaft; *C* is clamped to *A* by the cap screw *E* and thus clamps the outer race *F*; G are the rollers; *H* is the thrust collar which bears against the outer race. The thrust is transmitted from the shaft through the sleeve *K*, to collar *J*, through roller thrust *I*, to collar *H*, and thence to outer shell. In illustration (3) the bearings are shown assembled on the armature shaft.





These are the parts of a roller bearing for a No. 3 type K Westinghouse motor.

This bearing has no thrust bearing or collar, inasmuch as the rollers and races are themselves able to take care of the thrust on the small size motor in which they are used.

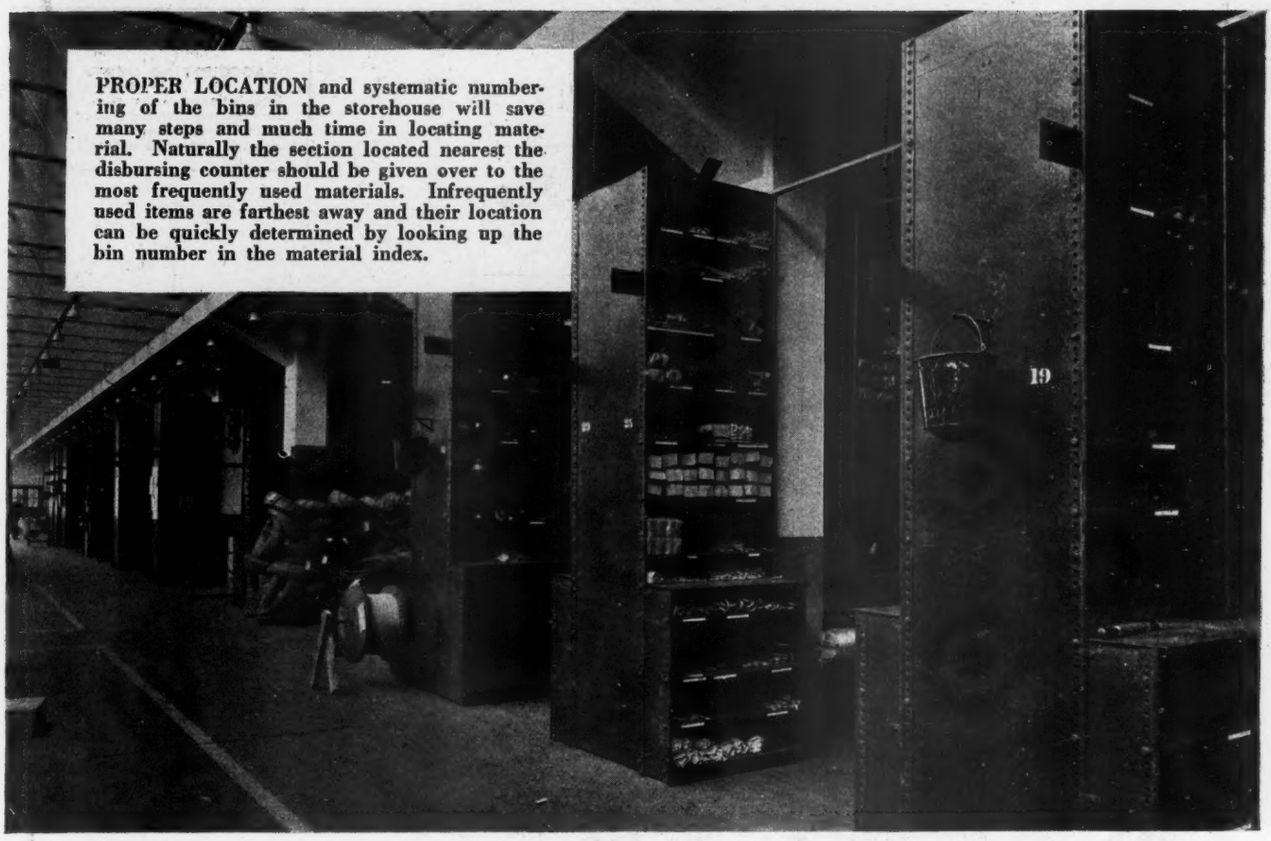
ruined, although the main bearing was not damaged. These bearings consume very little grease and I was once asked why I put on grease cups. The chief reason is that if bearings which are not fitted with grease cups should start to heat there would be no way of putting grease in them. We often find that the best of grease evaporates to some extent and that the addition of a certain amount of fresh grease is of considerable value.

Three hundred sets of roller bearings are now in operation and practically no failures have resulted. From my experience with these bearings I have found that their use results in reduced electrical repair, diminished commutator wear, reduction of band breakage, less pinion maintenance, reduced expense for inspection and lubrication, and less delay time charged against the electricians. These statements are amplified and explained in the box tabulation shown on page 167.

In my opinion the extra expense of anti-friction bearings is more than justified in the savings effected in repairs. As an example, the first installation which I described ran three times as long as we had any reason to estimate it would. This in itself probably paid for that set of roller bearings and the set is still in service and is going to run a long time unless poor grease or an accident puts it out of commission. Before roller bearings were installed in the motors in the plant with which I am connected, there were an average of 165 to 175 armatures at a time in the shop undergoing repairs. Since roller bearings have been installed the highest number of armatures in the shop at any one time was 125 and the average number is 100. I do not know of any condition that could cause this reduction of armature failures, other than the application of roller bearings. I am convinced, therefore, that the mill-type motor with babbitt bearings will be supplanted soon by the roller-bearing motor. It has been proven to my entire satisfaction that by careful designing, roller bearings can be applied to practically any motor at a saving that will soon repay the extra initial cost. When this is fully appreciated by mill engineers, as it is now by some, roller bearings will be written into motor specifications.

The motor shown in this application has roller bearings on its armature shaft.

In the illustration at the top are shown the service conditions under which the motor operates. The drive is located in a pit at one end of the soaking pits of a blooming mill. The motor drives a sheave wheel through two gear reductions. The sheave wheel pulls a cable which draws an ingot buggy carrying the ingots from the soaking pits to the mill approach table. The drive is subjected to plugging and sometimes to "inching" the buggy a short distance. In the bottom illustration the closeup view shows the dirt, grease and oil which surround the drive.



PROPER LOCATION and systematic numbering of the bins in the storehouse will save many steps and much time in locating material. Naturally the section located nearest the disbursing counter should be given over to the most frequently used materials. Infrequently used items are farthest away and their location can be quickly determined by looking up the bin number in the material index.

Step by Step Details for

Obtaining Equipment and Supplies for Maintenance

Of an Industrial Works, together with Methods of Storing and Accounting for the Material from the Time It Is Received Until It Is Used

By J. ELMER HOUSLEY

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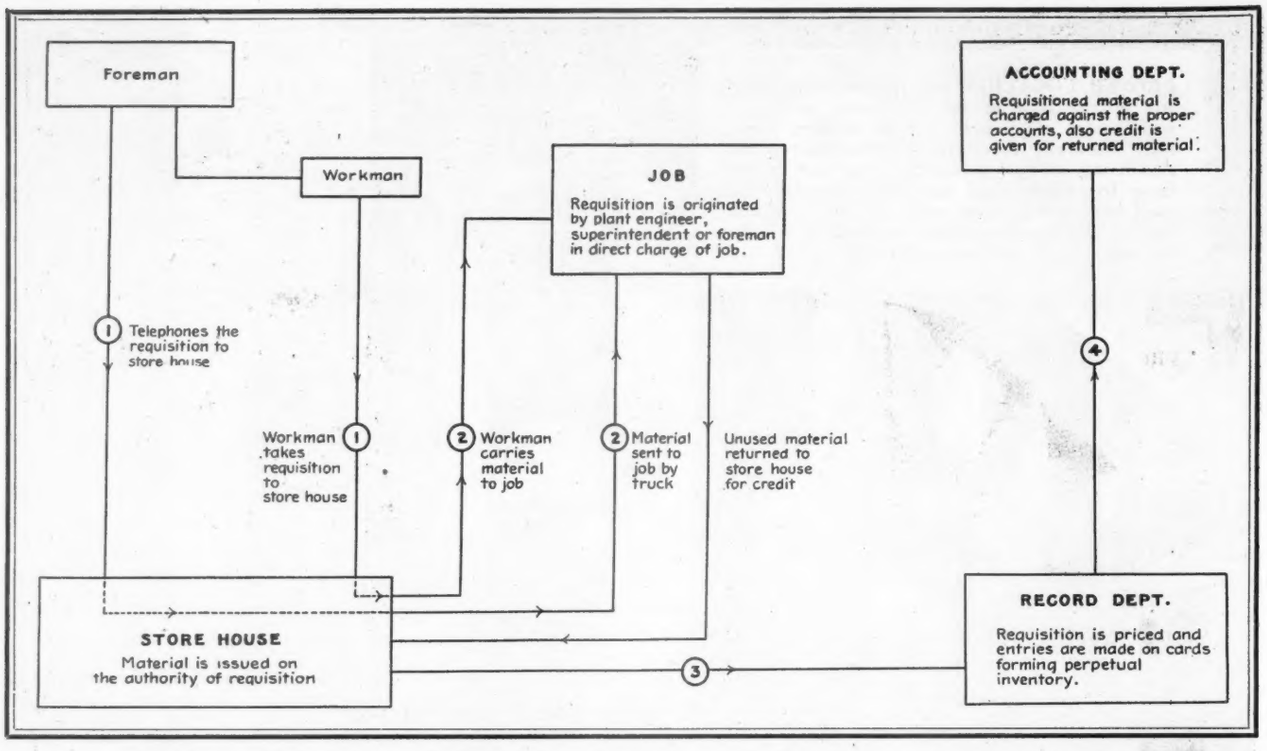
THE FUNCTION of the storekeeping department of an industrial plant may be compared to the service performed by a single large department store supplying a city. The size of the department store and the kind of commodities handled are determined by the requirements of the customers. Considering the single unit of electrical stores, the requirements of such a department are analyzed by the same methods that the merchant would use. Success is measured by the quality of service given. Real service means that there must be maintained at all times an adequate supply of materials for construction and maintenance work in the plant. The rate of turnover must be watched on all items in regular use and the wants for special jobs and seasons must be anticipated. Under centralized control of the purchasing agent materials are collected from jobbers, manufacturers, sales agents and other dealers, checked, and put in stock until ready to be utilized on the job.

THIS ARTICLE TELLS how the industrial plant organization determines what material it will need in the future, what is done to obtain it, how the required material is gathered from a great variety of sources, how it is stored until a breakdown requires a particular repair part or the material is needed in the construction of a certain job and how the given material is kept track of, from the time the need for it is foreseen until it is actually used on the job.

The centralized control of material in a general storehouse is a great advantage over the method of having each plant department store the materials required by that department. Loss of material is minimized, duplication of stocks is eliminated and overhead is cut down. Access to the material is not obtainable except by those regularly employed in the storeroom.

Storehouse Equipment Should Be Arranged Conveniently

The physical equipment of the storehouse of the plant in question consists of sectional type of metal framework arranged to form bins. The size of the bins is adjustable and may be changed as the stocks of given items carried, may change. These bins are arranged in stacks placed back to back with an aisle in front of each stack. At a convenient counter height is an extension shelf. This gives more space in the bins below the shelf and also provides a convenient place for material when checking, or the shelf may be used as a step in reaching the higher bins. The construction of the equip-


Foreman
Workman
JOB
Requisition is originated by plant engineer, superintendent or foreman in direct charge of job.
ACCOUNTING DEPT.
Requisitioned material is charged against the proper accounts, also credit is given for returned material.
1 Telephones the requisition to store house
Workman takes requisition to store house
1
2 Workman carries material to job
2 Material sent to job by truck
Unused material returned to store house for credit
4
STORE HOUSE
Material is issued on the authority of requisition
3
RECORD DEPT.
Requisition is priced and entries are made on cards forming perpetual inventory.

This diagram shows how the desired material gets from the storehouse to the job and how the proper department is charged for the material.

ment is such that a shelf may be changed to a bin simply by adding a bin-front attachment, or the shelves may be split up into any desired arrangement by crosswise or lengthwise dividers. Drawers of various sizes are provided to fit on part of the shelves. On each bin shelf or drawer is a cardholder which carries the bin number and a description of the material located in that compartment.

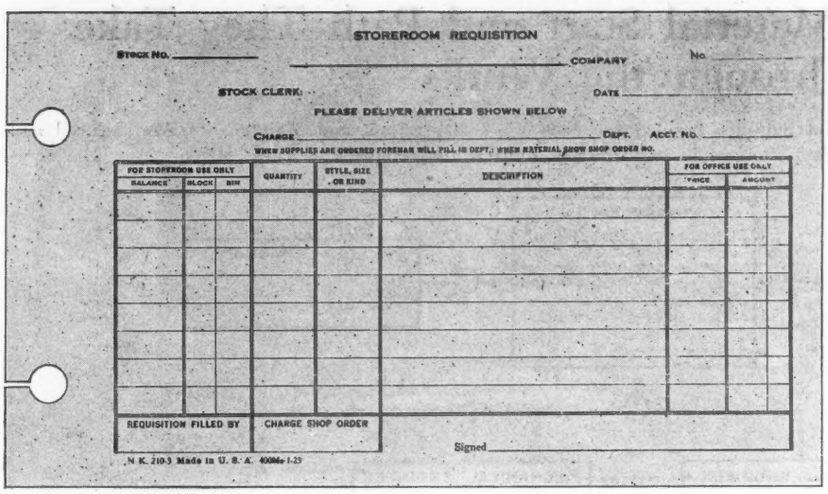
Near the rear of the storeroom, shelves are provided for the material that is too large to be conveniently stored in bins. The two sections nearest the counter or window through which material is delivered are given over to the most commonly used items such as bolts, nuts, and screws. Then comes the fuse link and fuse stock section. The next section provides for conduit fittings, wiring and insulating materials. The fifth section provides for compensator fingers and contacts, repair parts for control equipment of electric trucks, locomotives, elevators, and other small drives. The next section is utilized for line hardware, insulators, and also potheads and other lead cable fittings. Shelves to one side and to the rear of the bin section are used for safety switches, meters, current transformers, lighting fixtures and reflectors. A reel of No. 14 wire is kept in this section. All other wire and cable, including a large stock of round and rectangular magnet wire for rewinding motors, is kept on the third floor of the storehouse. On the fourth floor, space is provided for compensators, motors and small transformers. The large transformers are kept outside in a crane yard as they are built for outdoor service and are not affected by weather. It is very essential to store motors and compensators in a heated building during the winter in order to prevent them from sweating, for moisture in the air condenses on the metal parts and deteriorates the insulating materials and rusts the iron parts. Small and valuable items such as flashlights and flashlight parts are kept under lock in the storekeeper's office. Material that is likely to be stolen, such as lamps, is kept in a "lock up" section of the main storeroom. All lamps are marked with the company name by means of an etching fluid.

Arrangements are made for convenient handling of the material both into and out of the storehouse and to the place where it will be used. Motors and compensators are handled by hand trucks and by platform lift trucks or handled on rollers using the skids attached to the motors for shipment. Incoming material may be handled directly from a railroad car at the storeroom dock or from a motor truck or industrial electric truck along the same dock. A monorail carriage with a 1-ton chain block is provided for unloading purposes. Motors weighing over 2,000 pounds are stored in a wing extending from the main floor of the storehouse, which also houses rough stores such as small castings, shafting, sheets, conduit and pumps.

The delivery of material from the storeroom to the jobs scattered over the large area of the plant is handled by electric industrial trucks.

Procedure for Obtaining Material from Storehouse

Withdrawal of electrical material can be made only by those in authority in the *Electrical Department*, or at night by the night master mechanic. Several sample signatures are furnished the storekeeper from each authorized person. Usually these will be the electrical engineer, chief electrician, office assistant, shop foreman and construction foreman. A storeroom requisition, or store ticket, signed by one of these men is taken for every lot of material issued from the storeroom. The storeroom requisition blank shown in one of the illustrations provides space for the job number. Whether the job is regular repair and maintenance, special repair and maintenance, or construction, is indicated by the series of numbers used. Space is provided for the



STOREROOM REQUISITION

Stock No. _____ _____ COMPANY No. _____

STOCK CLERK: DATE _____

PLEASE DELIVER ARTICLES SHOWN BELOW

CHARGE _____ DEPT. ACCT. NO. _____

WHEN SUPPLIES ARE ORDERED FOREMAN WILL FILL IN DEPT.; WHEN MATERIAL SHOW SHOP ORDER NO.

FOR STOREROOM USE ONLY			QUANTITY	STYLE, SIZE OR KIND	DESCRIPTION	FOR OFFICE USE ONLY	
BALANCE	BLOCK	BIN				PRICE	AMOUNT

REQUISITION FILLED BY | CHARGE SHOP ORDER | Signed _____

N K. 210-3 Made in U. S. A. 400Me 1-23

quantity and description of the material. The price extensions are made by the record clerks in the *Record Department.*

The procedure in putting through a storeroom requisition, except for very small items passed over the counter on presentation of a requisition, is as follows: The foreman telephones to the order clerk in the storehouse, giving his name, job number, the building station number where the material is to be delivered, and the quantities and items desired. The storehouse clerk takes the requisition, assembles the items and places the requisition in a binder which has the building number stamped on the outside. The truck driver gathers the material intended for the buildings on his assigned route, loads up his truck and takes the material to the point designated as the station shown on the requisition. The mechanic on the job signs for the material. Hence it is seldom necessary for a mechanic or helper to leave the job to secure material.

The record of storehouse transactions is handled by a sort of clearing house called the *Record Department.* A card index system covering every item in stores is arranged to form a perpetual inventory. Receipts and withdrawals of material are entered on the cards and each card is balanced to show the amount of that item remaining in the bin. Each card is marked with the bin number housing that item. The bin and shelf divisions are lettered alphabetically, a letter to each side of a double stack of bins, and the bins are numbered from one up on each side of the stack. If a material item card states that the material is located in bin H2, it is a simple matter to walk to the rear side of the fourth section and reach the item on the top row of bins, the second bin from one end of the stack. The invoice is used for entering the items on the record cards together with the cost of that lot of material. The date of entry is noted on the card. The withdrawals are entered from storeroom requisition blanks with the date of requisition noted. The additions and subtractions are balanced at all times and the quantities of any given item may be known at once by referring to the material card. A valuable function of this card is to furnish information as to the rate of consumption of material over any given period. This will be considered later.

Material is obtained from the Storehouse on this requisition.

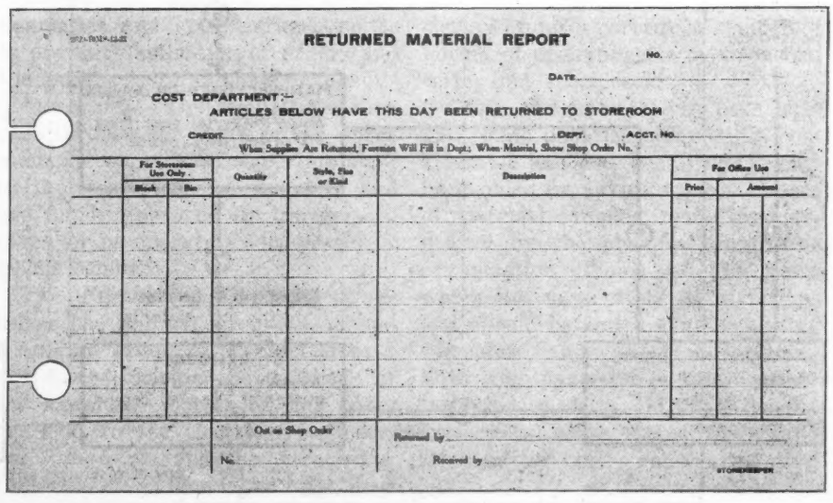
This is known as the storeroom requisition or store ticket and is the authority for the *Storehouse* to disburse the required material. This form also shows the *Accounting Department* what job or department is to be charged for the material requisitioned.

Since the cost of different shipments of the same item may vary, the average cost is used in pricing the storeroom requisitions. After the quantities are entered on the record card the storeroom requisition is sent to the *Accounting Department,* where the items and costs are entered in the accounts against each job number. In this way accurate costs are obtained for any construction, repair or operation job. Material which is left over on a job, if in good shape, is returned to the storeroom with the "Returned Material Report" blank shown in an accompanying illustration. This form gives the shop order number or the department to be credited, together with quantities and description of items.

When and How the Purchase of Supplies Is Authorized

One of the most interesting and difficult phases of maintaining electrical stores is the determination of stock requirements. The storekeeper is required to maintain a stock of the staple articles which are in every day use and consumed at a definite rate. The "ordering point" or the minimum stock on hand when more material should be reordered, is determined by the storekeeper, the electrical engineer and the chief electrician. The factors considered are the nature of the material, the quantity normally consumed in ninety days, the prevailing delivery schedules and whether the market is advancing or declining. The quantity to be ordered is usually the consumption for the previous ninety days.

The repair parts, whether special



RETURNED MATERIAL REPORT

No. _____

DATE _____

COST DEPARTMENT:—

ARTICLES BELOW HAVE THIS DAY BEEN RETURNED TO STOREROOM

CREDIT _____ DEPT. _____ ACCT. NO. _____

When Supplies Are Returned, Foreman Will Fill in Dept.; When Material, Show Shop Order No.

For Storeroom Use Only		Quantity	Style, Size or Kind	Description	For Office Use	
Block	Bin				Price	Amount

Out on Shop Order No. _____

Returned by _____

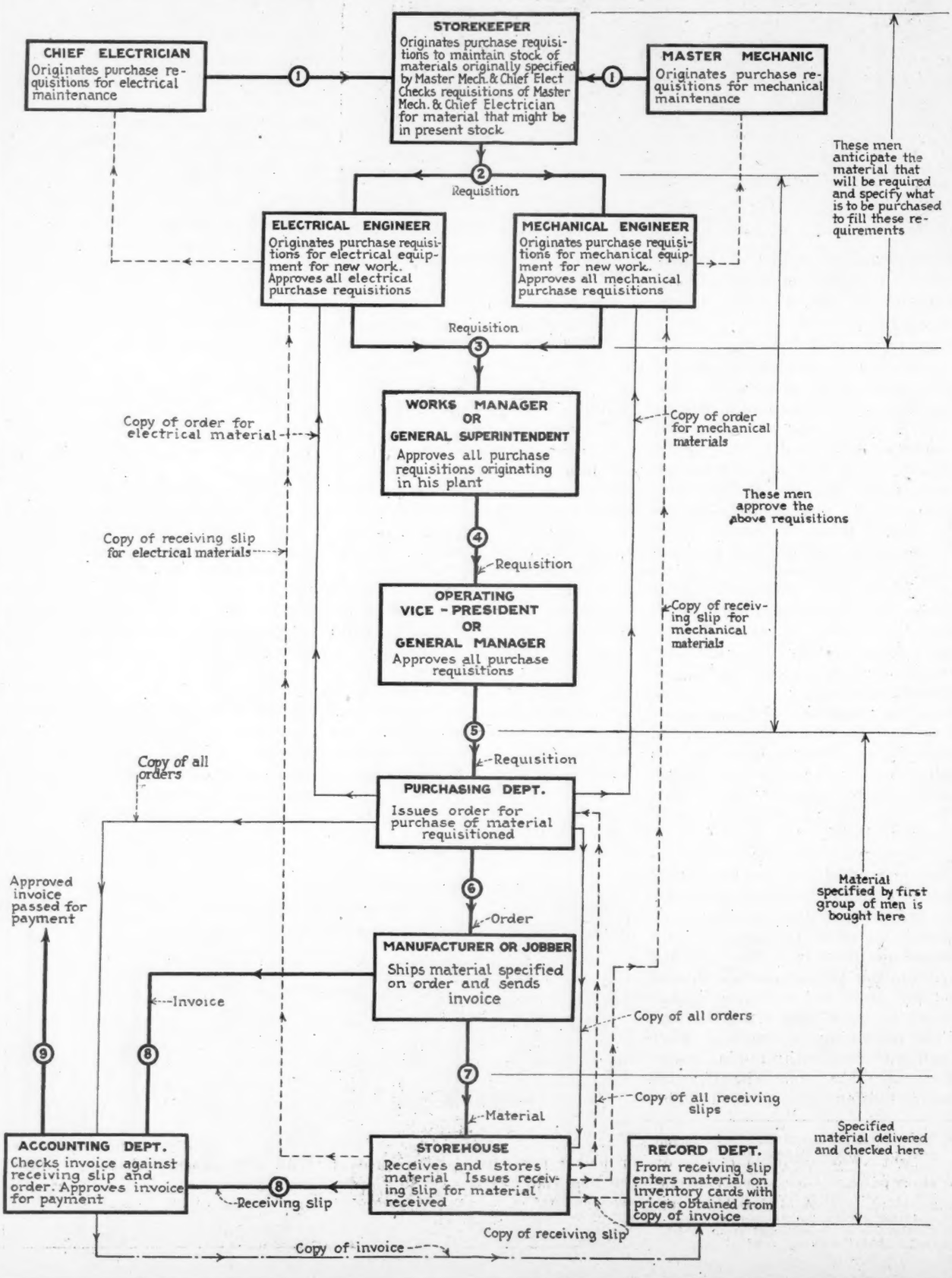
Received by _____ STOREKEEPER

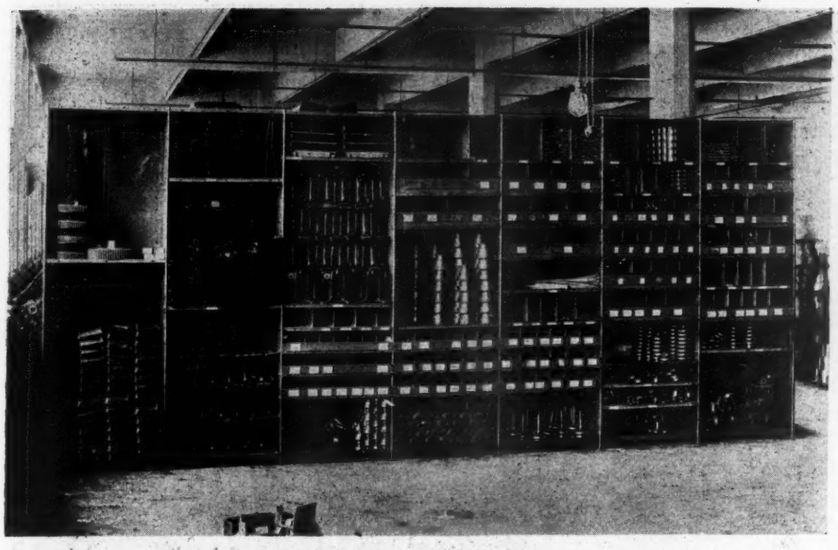
This form is used for returning material to the Storehouse.

This is known as the returned material report or credit memorandum. By the use of this form the *Storehouse* acknowledges the return of the material and the *Accounting Department* credits the job or department from which the material was returned.

How Orders for Material Start and Path They Take Through the Works

Including the Steps by Which Equipment and Supplies Needed for New Work, Operation, and Maintenance Are Secured and Delivered to the Works. The Numbers in the Diagram Indicate the Sequence of These Steps


CHIEF ELECTRICIAN
Originates purchase requisitions for electrical maintenance
STOREKEEPER
Originates purchase requisitions to maintain stock of materials originally specified by Master Mech. & Chief Elect
Checks requisitions of Master Mech. & Chief Electrician for material that might be in present stock
MASTER MECHANIC
Originates purchase requisitions for mechanical maintenance
1
1
2
Requisition
These men anticipate the material that will be required and specify what is to be purchased to fill these requirements
ELECTRICAL ENGINEER
Originates purchase requisitions for electrical equipment for new work.
Approves all electrical purchase requisitions
MECHANICAL ENGINEER
Originates purchase requisitions for mechanical equipment for new work.
Approves all mechanical purchase requisitions
Requisition
3
WORKS MANAGER OR GENERAL SUPERINTENDENT
Approves all purchase requisitions originating in his plant
Copy of order for electrical material
Copy of order for mechanical materials
These men approve the above requisitions
Copy of receiving slip for electrical materials
4
Requisition
OPERATING VICE-PRESIDENT OR GENERAL MANAGER
Approves all purchase requisitions
Copy of receiving slip for mechanical materials
5
Requisition
Copy of all orders
PURCHASING DEPT.
Issues order for purchase of material requisitioned
Approved invoice passed for payment
6
Order
Material specified by first group of men is bought here
MANUFACTURER OR JOBBER
Ships material specified on order and sends invoice
Invoice
Copy of all orders
9
8
7
Copy of all receiving slips
Material
ACCOUNTING DEPT.
Checks invoice against receiving slip and order. Approves invoice for payment
STOREHOUSE
Receives and stores material Issues receiving slip for material received
RECORD DEPT.
From receiving slip enters material on inventory cards with prices obtained from copy of invoice
Specified material delivered and checked here
8
Receiving slip
Copy of receiving slip
Copy of invoice



This picture shows how conveniently steel shelving or bins can be subdivided to suit the material in them.

As the stock varies the size of the bins may be expanded or contracted to suit the requirements. Some of the shelves pictured are carrying loads of 2,000 lb.

or regularly used, are specified on a purchase requisition by the chief electrician who is in close touch with the repairs under way. The quantities used during a given period are subject to erratic variations. These are influenced by conditions in the operating department, the labor turnover (indicating the number of green operators), and the skill and morale of the repair organization. With such items as compensators and switches, if a sufficient number of spares are on hand it is well to let the damaged equipment accumulate in the shop for one or two months and then order about double the quantity of material necessary to repair the equipment on hand. Parts such as fingers and contacts for compensators and controllers are usually ordered in lots of 100, 50 and 25 pieces as determined by the amount of such apparatus in service and our experience as to the life. The small fingers and contacts usually last from one to one and one-half years and in the larger control equipment from two to three years. In ordering magnet wire, close check is made of the number of times we have re-wound motors using a common size of magnet wire. If this is not done a surplus stock of rectangular wire is likely to accumulate and remain in stores for a long period of time as an idle, interest-eating investment. For motors having sizes of wire seldom used we delay buying wire until the motor comes in for repairs and the minimum amount of wire possible is bought. For special apparatus of vital importance one set of necessary parts is kept on hand and replacements are ordered as these parts are used. This applies to parts for elevators, automatic telephones, cranes, automatic control, fire alarms and similar equipment.

The electrical engineer originates purchase requisitions for electrical material intended for new work. In case the job will amount to more than $500, a special authorization is prepared with estimates of cost and necessary data as to why the job is required or what savings will be obtained by its installation. After it has been approved by the higher executive officials of both the local and the parent companies, the required material is requisitioned.

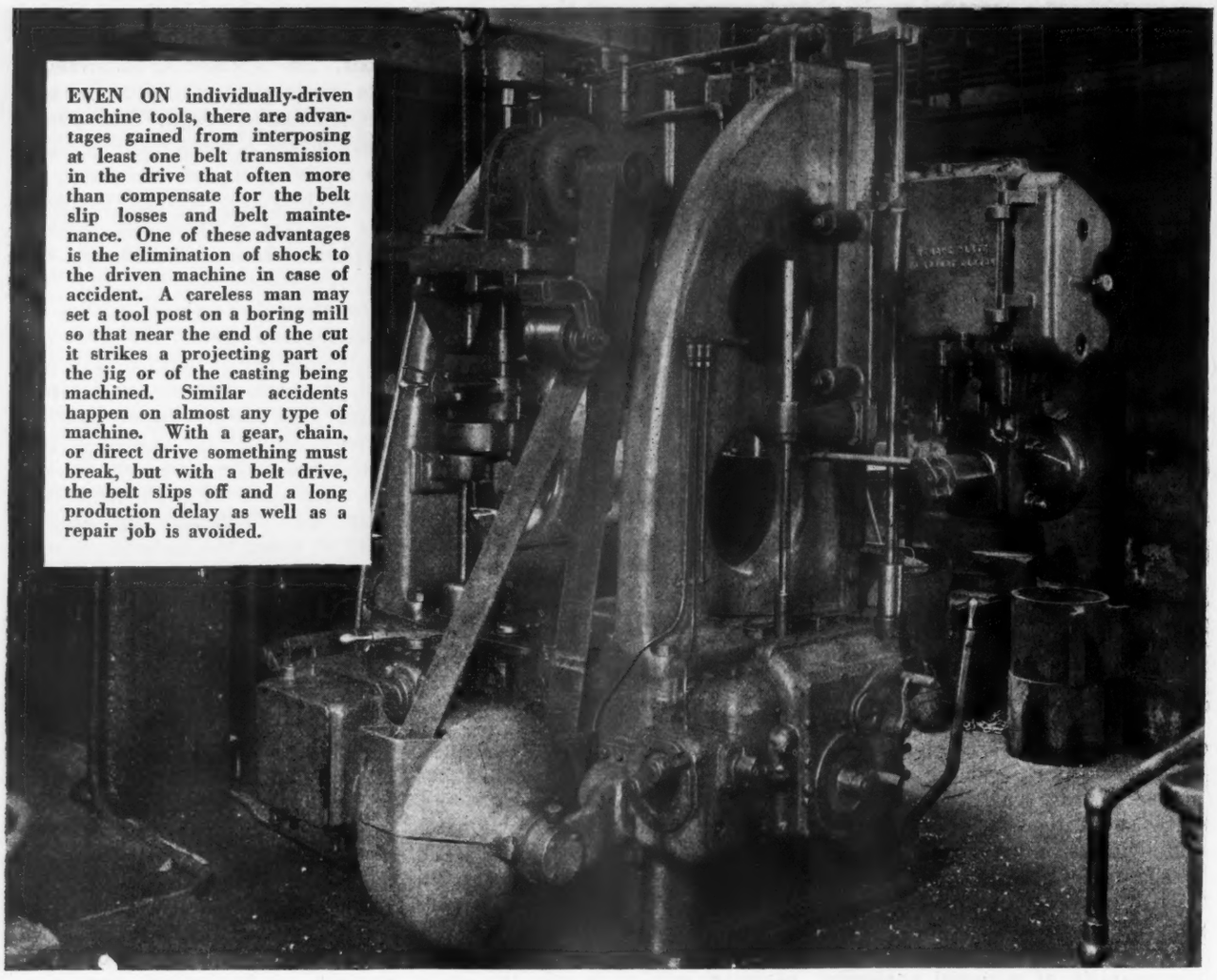
All purchase requisitions from the storekeeper for electrical material and from the chief electrician pass through the hands of the electrical engineer for approval as to the quantities and specifications, so as to prevent duplication of orders and the purchase of obsolete or unsuitable material. The requisitions then pass through the hands of the works manager or general superintendent of the local plant for approval and are finally approved by the general manager or operating vice-president of the company.

The *Purchasing Department* receives the approved requisition and issues an order to a manufacturer or jobber covering the purchase of the material. Copies of this order are sent to the electrical engineer, the *Storehouse* and the *Accounting Department*. The manufacturer ships the material to the plant and sends the invoice covering the goods. The *Accounting Department* gets the invoice and the *Storehouse* receives the material. The *Storehouse* makes a memorandum, called the receiving slip or the receipt entry, of the goods received. Copies of this are sent to the electrical engineer, the *Record Department* and the *Accounting Department*. The *Accounting Department* checks the receiving slip against the order and the invoice and if everything is correct, it passes the invoice for payment. The *Record Department* receives a copy of the invoice so that it may make the entries on the record cards covering the items of material, and determine the average price at which the material is to be charged out.

A copy of all *Purchasing Department* orders for electrical materials is furnished to the electrical engineer.

Certain items carried in the electrical stores should be bought on specification and tests made on the material upon arrival in the receiving department. This applies chiefly to large plants where the material is bought in fairly large quantities and usually direct from the manufacturer. The smaller companies should make less elaborate tests, based somewhat on rule-of-thumb methods or a physical comparison between samples taken from orders from various firms. Where possible the electrical engineer should work with the chemical engineer and determine the physical and chemical nature of the material to be purchased before writing up specifications. They should also develop a routine method of testing the material received. At times material may be checked in by a receiving clerk without a careful or competent noting of discrepancies between material and specifications.

Often the material has been used and found unsatisfactory and a considerable loss may result which may be avoided by having certain classes of material sampled, tested and approved by the chemical engineer's organization. Some of the items which are susceptible to variations and should be tested are: insulating varnishes and paints, insulating cloth and paper, web tape, rubber insulated wires, acid and caustic battery solutions, transformer and compensator oils and lubricating oils.



EVEN ON individually-driven machine tools, there are advantages gained from interposing at least one belt transmission in the drive that often more than compensate for the belt slip losses and belt maintenance. One of these advantages is the elimination of shock to the driven machine in case of accident. A careless man may set a tool post on a boring mill so that near the end of the cut it strikes a projecting part of the jig or of the casting being machined. Similar accidents happen on almost any type of machine. With a gear, chain, or direct drive something must break, but with a belt drive, the belt slips off and a long production delay as well as a repair job is avoided.

Some of the Hows and Whys for

The Layout of Group and Individual Drives

Together With Special Features Determining the Layout of Fan Drives and the Results of Tests on Lineshaft Friction Losses

By ROBERT W. DRAKE

Electrical Engineer, McCormick Works, International Harvester Company, Chicago, Ill.

A DETAILED ANALYSIS of the reputed advantages of individual drives compared with group drives will show that the latter have a much wider field than is commonly supposed. However, each type of drive has its field where it is generally admitted to be unwise to attempt to apply the other. The following article offers suggestions for the layout of belts, gearing and direct connection as applied to both individual and group drives. Belt drives should be designed conservatively, especially the drive from motor to lineshaft. The arguments against group drive based on speed variation, belt slip and the like, can be almost entirely eliminated by designing drives with bottom pull on the belts rather than top pull, and with ample belt area. Mr. Frederick W. Taylor's classical paper* in which he proves that, all relevant factors considered, the total annual cost of belt drives is least when the belt tension is approximately half the usual American practice, is as true now as it was when he made his painstaking experiments.

The horsepower that may be transmitted by a belt varies with the belt speed, other factors remaining constant. However, at speeds above 5,000 ft. per minute, the centrifugal force tends to lift the belt from the pulley and so decreases the friction contact which gives a belt its pulling power. The best belt speed is about 4,000 ft. per min. Most standard motor pulley sizes are not large enough to give this speed. Where the space between lineshaft and ceiling is sufficient, it is better to install a large lineshaft pulley and a motor pulley large enough to give approximately the above speed. The decreased bearing troubles due

*Proceedings A. S. M. E., Vol. 15.

to diminished belt stresses, the reduced cost of belting and lessened slip will repay careful design in each case.

In the case of machine tools, there are also sufficient advantages in interposing at least one belt transmission in the drive, so that this has of late years become standard practice in many progressive industrial plants, even on individually-driven machines. Where such practice is deemed best about half the belt-slip losses and belt maintenance are retained in order to gain advantages which more than compensate.

One of the advantages is the elimination of shock to the driven machine and to the motor in case of accident. Such accidents are of daily occurrence in a large, individually-driven plant. A careless man sets a tool post on a boring mill so that near the end of the cut it strikes a projecting part of the jig or of the casting being machined. Similar "accidents" happen on almost any type of machine. With a gear drive something must break but with a belt drive the belt slips or comes off and a long production delay as well as a repair job is avoided.

Attempts have been made to design this type of belt drive so that the driving motor could not be so grossly overloaded. This has not proved practicable. Many such drives must start against a severe inertia load, and must carry an intermittent load with relatively high peaks. Anything short of a very conservative belt drive will give constant trouble at such times and offer more handicaps to output than it eliminates.

Recommended Standard Speeds for Each Size of Motor

In the preceding articles in the February and March issues, much stress has been placed on spares. In a plant in which group drive is the rule, the choice of a standard speed in each motor size is of importance. A proper compromise between the conflicting demands of the different sorts of service for which motors will be needed, will minimize the number of "off standard" motors which must be tolerated (and duplicated if they are on important drives). It is necessary also to keep in mind the fact that the higher the speed of the motor, the lower the cost, and the higher the efficiency and power factor. Everything considered, I have found the following to be the most desirable speeds in 60-cycle, alternating-current motors:

¼ to 3 hp	1,200 r.p.m.
5 to 50 hp	900 r.p.m.
75 to 100 hp	600 r.p.m.

THIS IS THE THIRD of a series of three articles that analyze the advantages of group and individual drives. The first article, which appeared in the February issue, pointed out the principal reputed advantages of individual drive. The second article was published in the March issue and discussed fully the principal reputed advantages of group drives. This article will offer suggestions for the layout and installation of individual and group drives.

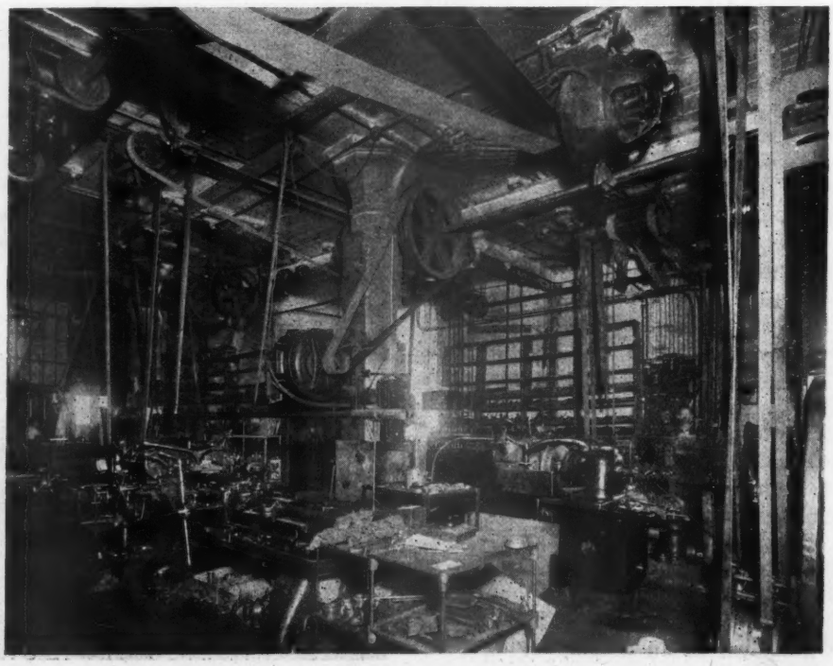
Factors Governing the Layout of Lineshafting

For general manufacturing the balance between cost, lineshaft losses and mechanical suitability is struck at about 200 r.p.m. for lineshafts serving groups; for shafts serving grinding and similar high-speed machinery exclusively, lineshaft speeds may sometimes be as high as 400 r.p.m. to advantage; for groups containing assorted woodworking machinery, a speed in the neighborhood of 300 r.p.m. generally works out best.

Countershaft Friction Is Major Part of Lineshaft Losses

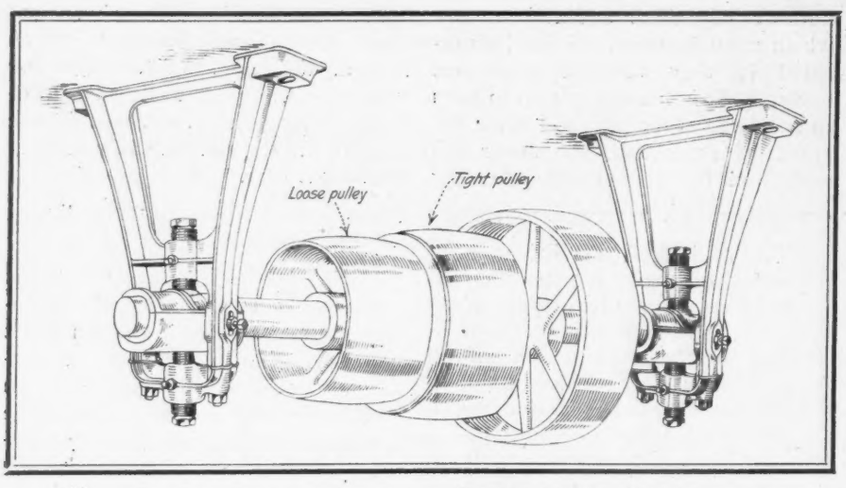
I will risk a digression at this point to discuss the results of a series of service tests on lineshaft friction. The tests were undertaken to obtain a service check on laboratory experiments on relative friction with babbitt bearings using various grades of oil, each with and without Achison's "Oildag" and were later extended to include ball bearings for comparison.

A room of woodworking machinery was chosen for the comparative tests because the lineshaft speed was 50 per cent higher than the lineshaft speed in general use throughout the plant, and the shafting friction losses might be expected to be thereby increased. The bearings were of the wick self-oiling type, a special design developed at this works in the old engine drive days. Wick-oiled bearings are nowadays considered to be old-fashioned, but this design is admirable indeed as to reliability and, by comparison with other published tests, has remarkably low friction. The wick design has one advantage that is seldom sufficiently emphasized and is a worthwhile advantage in dirty locations; this is the fact that the oil, in recirculating, passes through the



The best belt speed is about 4,000 ft. per min.

However, the difference between the required lineshaft speed and the motor speed may be so great that it is impracticable to use pulleys large enough to secure the proper speed reduction and maintain such a belt speed. In the picture shown this is the cause for the low belt speed. One way of getting around this is to make the speed reduction in two steps, using a jackshaft between the motor and the lineshaft.



Special design of tight and loose pulleys which is arranged to reduce friction losses when idling. The loose pulley is somewhat smaller in diameter than the tight pulley so as to relieve the belt tension when idling, thereby prolonging belt life and decreasing bearing friction. The loose pulley is wider on the flange side and has a higher crown than the tight pulley. This keeps the belt in the center of the loose pulley and prevents wear on the edge of the belt.

wick by capillarity, and thereby the dirt and grit are separated out. The decreased wear from this cause is very marked, especially in foundries and other places where abrasive dust is normally present in the air.

To accurately determine the power required to run the shaft under test, a special small motor was belted to it, in place of the large motor required to carry the regular load when the driven machines are running. The input to this motor was determined each day at noon with shaft running, but all machines shut down. A week or more was allowed after each change in lubricant for bearing conditions to become constant. After several months comparative testing with different oils in babbitt-lined bearings the main lineshaft was equipped with ball-bearing hangers, but the looked-for startling reduction in friction did not appear. This suggested that a determination be made of the main lineshaft friction with no countershafts running. We were surprised to find that only 17 per cent of the friction in this room was in the main lineshafting, and that the remaining 83 per cent was in the countershafting.

When the drive belts on the ordinary "tight and loose" style of countershafts are on the loose pulley they sometimes take such a position that one edge drags on the tight pulley for ⅛ in. to ¼ in. This seemed to be a partial explanation of the relatively high countershaft friction in this case. A design of loose countershaft pulley somewhat smaller than the tight pulley, with flanged approach to the diameter of the tight pulley and a rather abnormal crown has been used more or less for many years, but has never come into common use. This design is shown in an accompanying illustration. Since the increased cost is trifling, it would seem in the light of this experiment to be worth adoption, at least in cases of special countershafts built within the plant, and in maintenance replacements.

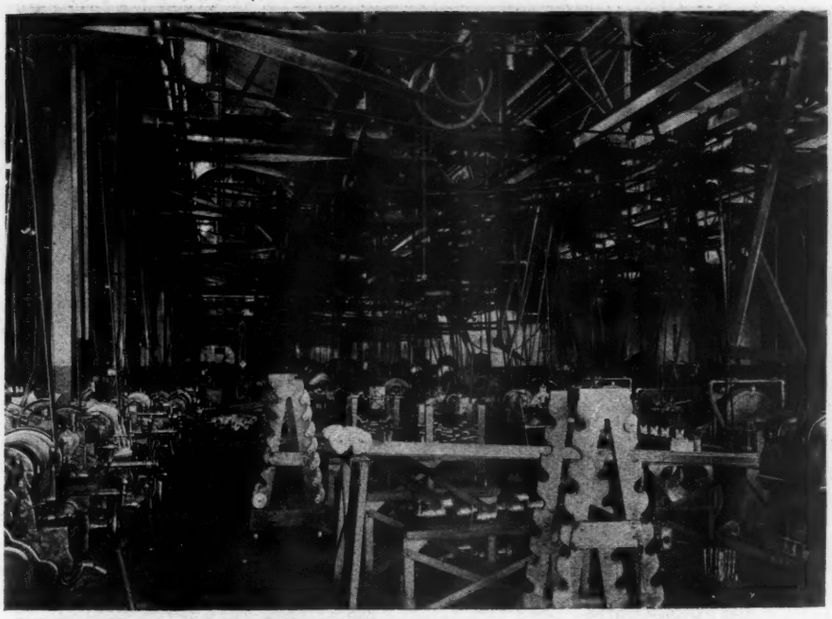
Slow-Speed Motors are Preferred for Geared Drives

Except in the case of very small motors (1 hp. and below) slow-speed motors are preferable for gearing if reliability is of any importance. The slower-speed motor is built in a larger frame with a heavier and sturdier shaft which is better able to endure the shock of gear drive. The slower shaft speed allows a greater pinion diameter without exceeding conservative peripheral speeds at the pitch line, and this in turn permits the use of a coarser pitch on the pinion, with consequent greatly increased life and reliability, on the first gear reduction. Especially is all this true of the excessively light designs of continuous-rated motors which have been marketed during the past few years by the larger manufacturers. The bearings in these motors are generally die-cast without shells. If satisfactory bearing life and reliability are to be obtained, it is almost necessary to operate such motors with compressed cloth, molded composition, or rawhide pinions. In applications where such pinions will not stand up it is advisable to use sturdier motors.

Considerations Affecting the Design of Fan Drives

In general, fans are best driven individually, but this is by no means a universal rule. Small and moderate-sized exhausters can frequently be grouped with the machines which they serve (for example, grinders, buffing wheels, and the like) while less frequently it is advantageous to group blowers with the machines served. The fact remains that even

A lineshaft speed of 300 r.p.m. generally works out best for groups of assorted woodworking machinery.



Many factors are involved in laying out a group drive similar to the one shown.

There is the determination of the motor speed to use, the most efficient belt speed, the factors governing the selection of pulleys, and the selection of the lineshaft speed, which is based on the balance between cost, lineshaft losses and mechanical suitability.

in plants which are group driven in general, most large and many small fans are individually driven. At first thought a direct-connected unit appears to offer many advantages, but I prefer to belt fans whenever possible. There are various advantages for and against this practice.

The exact predetermination of performance in a fan system is more difficult than most ordinary engineering layouts. It is much easier to predetermine pressure drops in electrical, steam, or hydraulic layouts than in fan piping. A fan system is full of bends, offsets and elbows, to avoid obstructions. These "fittings" can seldom be made to follow any definite standard as to curvature, but owing to the relatively large size of ordinary fan piping, they must be laid out individually to suit the space available. Frequent changes from round to rectangular ducts and back again are often required. Estimates of resistance to flow through such "fittings" are of necessity rough. In water, steam and electric transmission, standard pipe (or conductors) and fittings are universally used and their resistance is known to a far greater degree of precision.

In steam and water piping the condition of the inside surface plays an important part in determining the resistance, but the effect of incrustation plays a less important part in determining flow than is generally the case with fans. The degree and rate of incrustation in fan piping depends upon so many variables that it varies from place to place in the same system of ducts (due to variation in velocity). Between different installations in approximately the same service, the variation in incrustation due to variation in oily vapor carried in the air, fineness and density of material handled, is astonishing. It is seldom possible to clean fan piping effectively except the main ducts, and these only when they are large enough for a man to pass through.

The result of all this is that once a fan system is in service, a little testing will very frequently show that a moderate change in pressure will be beneficial. Such a change can best be effected by varying the speed of the fan. The pressure delivered by a fan connected to a fixed duct system varies as the square of the speed and the horsepower required to drive it varies as the cube of the speed. Thus if tests show that a decrease of as little as 10 per cent in speed will give satisfactory performance, there will be a saving in horsepower of 30 per cent. When we consider that the power required to operate an average exhauster system using efficient modern slow-speed fans serving woodworking equipment or grinding machinery often equals or exceeds the power requirements of the machinery served, it is evident that such a saving is well worth while. If the case is reversed, and the operation of the fan is less satisfactory than expected, frequently a slight increase in speed will set matters right again and give ideal service. As time goes on, the resistance of the pipe frequently increases with gradual roughening of the pipe due to deposit of foreign matter. Eventually a higher pressure or suction is necessary to obtain good results.

From time to time load may be added or removed from the system, increasing or reducing the horsepower and in some cases the speed required to drive the fan for satisfactory operation. Within reasonable limits, all such changes in condition may be met by changes in the speed and horsepower of the fan drive. No such changes are ordinarily possible with a direct-connected fan, particularly with alternating-current drive. With a belted fan small changes may be effected at a minimum expense, delay, or trouble by merely changing motor pulleys. Greater changes requiring a change in horsepower outside the economical power factor and efficiency range of the motor originally installed, or beyond its capacity, can be easily made by a change to the next size of motor with a suitable pulley.

Belting fans has the great advantage that it permits the use of motors which are standard as to speed and horsepower for lineshaft drive in the plant and for which spares are therefore available in case of motor trouble. Further, the time required to replace a burned-out motor is ordinarily far more with a direct-connected unit than with a belted unit unless a flexible coupling is used with the former.

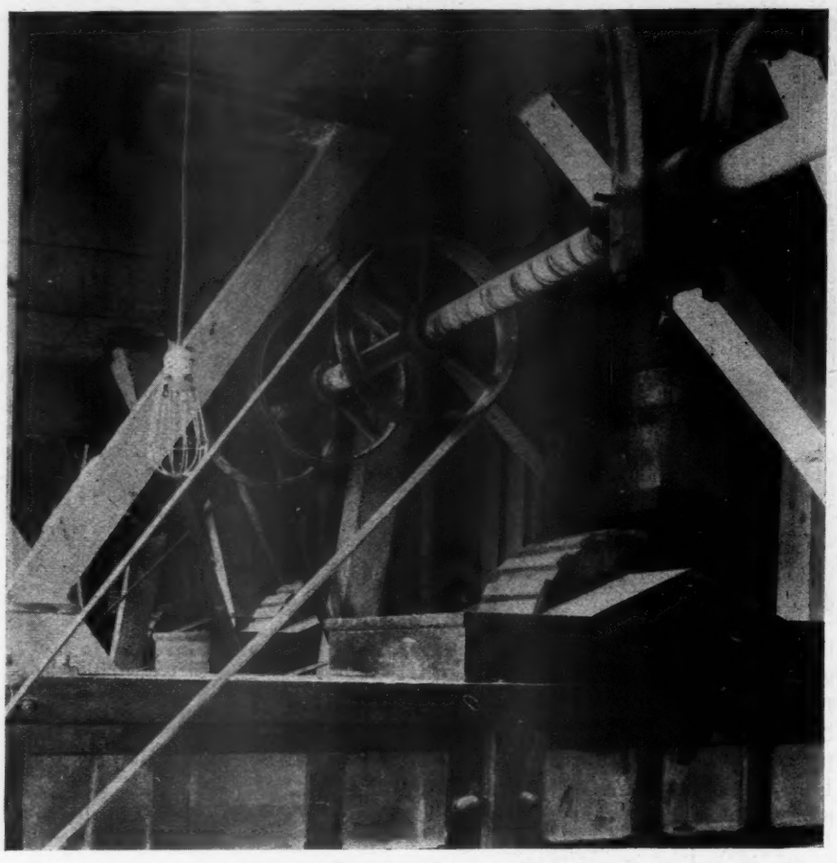
Frequently the necessity of increased capacity, discontinued process, rearrangement of machines served or some such trouble retires a fan from service. In such a case in a large plant, an opportunity to use a belted fan to advantage elsewhere will generally soon occur. Usually, the required speed will be quite different and the service and capacity different. With a belted fan this simply means putting it into service again with a different shop standard size of motor and an appropriate motor pulley. With a direct-connected fan the case is quite different. It is likely to be many years before the same combination of frame size of fan and motor size and speed is needed again.

EFFECTIVE power transmission occupies a more important place in the economical operation of mills and factories than is ordinarily attributed to it. Altogether too often the whole power transmission system is considered o. k. as long as the wheels will turn. However, no unit of the system is carelessness- or neglect-proof, as was brought out in other articles. One of the principal causes of trouble lies in the assumption that, once installed, each unit "stays put" in its relation to the others. In this, shafting, on either line- or countershaft, is perhaps the worst offender and usually gets the least blame, since the trouble backs up into bearings, couplings, belts or chains, or other units. Shafts put in alignment and kept that way go far toward obtaining smooth and economical operation of a shop.

Things to Know About

Line-Shafting and Hangers

When They Are Used as the Backbone of Power Transmission Where the Groups of Machines Are Driven As a Unit



Dust is an important factor in the operation of this installation of roller-bearing hangers in a flour mill.

By FRANK E. GOODING
Associate Editor, Industrial Engineer

IN THE early days water wheels and steam engines supplied the driving force in most plants and were connected to large headshafts by belts or ropes, or in the case of water wheels, sometimes by gearing. These head lineshafts in turn operated several lines of smaller shafting. With the increasing application of motor drives in mills and factories, the single large driving unit has been subdivided into several smaller power units each connected to an individual machine or to lineshafts in turn driving a group of machines. This has eliminated the friction loss of the heavy head shafting and provided a more flexible arrangement as shafts can be driven at an angle or any distance from the main drive unit without difficulty.

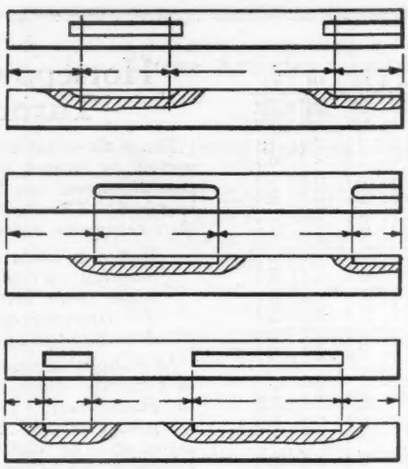
It is not the purpose of this article to discuss relative merits of group and individual drives and the types of work to which they are best adapted. This is taken up in a series of three articles on "When to Use Group and Individual Drives," the first and second of which appeared in the February and March issues of the INDUSTRIAL ENGINEER; the third and last article begins on page 174 of this issue.

Shafting as used in the ordinary industrial plant consists of a round bar of steel turned from a hot-rolled bar. This makes it perfectly round and of a standard diameter so that stock sizes of pulleys, flanges, couplings, clutches, bearings, and other similar mechanical power transmission equipment will fit on it without re-boring them to a gage fit. Also when removed from one shaft they will fit on another of the same dimension. Some old shops use a cold-rolled or drawn steel shafting. Cold-rolled shafting is made, as the name implies, by passing the rough bar cold through various grooves of a finishing rolling mill, which reduces it to the required diameter. Drawn shafting is made by drawing cold bars through dies of the specified diameter. In both types of shafting the diameter and shape is not quite as standard as it is with turned shafting and also a hard shell or scale forms on the surface. When this shell or skin is cut, as is necessary when key seating or doing other machine work, the shaft will bend or spring so that it is almost impossible to straighten it again. Because accuracy in shape, diameter, and straightness, as well as the possibility of cutting keyways without distortion, are some of the most important characteristics of shafting, turned shafting is generally used. However, some old installations of the other types are still in use.

In the manufacture of turned shafting the hot-rolled bars are first straightened and then turned and polished in automatic lathes. Since the bar is hot rolled there is not as much of a strain set up in the skin or shell of the bar, as was the case with cold-rolled or drawn shafting. Because all this thin skin is taken off when the shaft is turned there are no remaining stresses in the shaft to bend it in case a keyway is cut. Also, in case the shaft becomes bent it is more easily straightened again. As these automatic lathes may be set to turn to a standard diameter, the shafting which may be bought from almost any dealer, is a standard size in all cases. However, in the purchase of shafting it is well to check the diameter, allowing for

a commercial tolerance of 0.008 in. An extra charge is made where exact size or to within 0.0015 in., or less, over or under, is required. For ordinary lineshaft work an accuracy of this amount is not necessary.

While shafting may be obtained in any diameter, certain sizes have become a commercial standard and in all cases where possible effort should be made to use these standard sizes as they have also become a standard for couplings, clutches, pulleys, and the other mechanical power transmission elements. In most cases an extra charge of about 10 per cent is added to the price of any of this equipment for having it bored to an off-standard size dimension. In addition, there is the difficulty of these mechanical power transmission elements not being interchangeable if of an off-standard size. These standard diameters are the same as shown in the tables on page 180 up to 5⅛ in. The diameters given above that dimension are special shafts. It will be noticed that in most cases they are 1/16 under an even inch, half-inch or quarter-inch dimension. For example, one standard shaft size is 2 15/16 inches. In this case, a 3-in. bar is turned down 1/16 in. To get an even 3-in. turned bar would require the next larger size commercial stock and could be provided, but at an extra expense. Shafting is sold by the pound, and the price fluctuates according to the price of steel. Most manufacturers require that orders for shafting of a special diameter, or if it must be within an extra close tolerance, call for not less than 2,000 lb., as these orders are made up special.



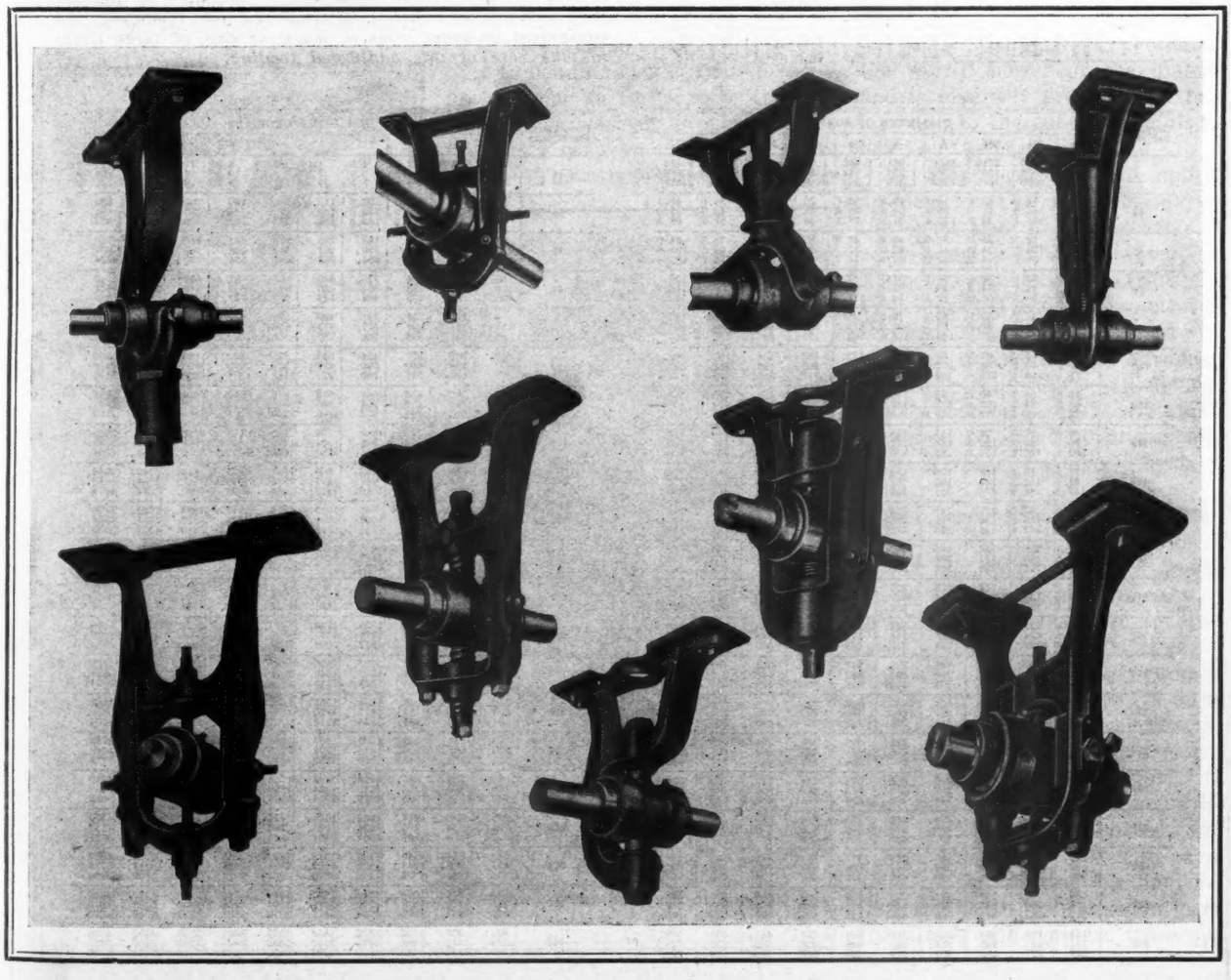
The different types of keyseats which are used in lineshaft work.

When an industrial plant orders the keyways cut before the shafts are delivered they should be careful to specify which type of keyways are required. Unless otherwise specified most manufacturers of lineshafting will cut keyways as in the top illustration, which shows the keyseat with the ends as left by the milling cutter. The middle illustration shows keyseats with round ends and the bottom level. The bottom illustration shows keyseats with square ends and bottom level.

The stock lengths of shafts vary somewhat among the different manufacturers and dealers but ordinarily shafts may be obtained in lengths of 10, 12, 14, 16, 18, 20, 22 and 24 ft. If odd lengths like 17 ft., 19 ft. or 20 ft. 3 in., are required they must be cut from the next standard length of bar, which is in even feet, and the entire bar is charged for, as well as for the cut-

This shows the construction of nine different types of standard lineshaft hangers.

The illustrations show the method of getting two- to four-point adjustment, and also the rigidity of the various types. Each of these installations is fitted with a special dumbbell, double-race, ball-bearing box.



Revolutions Per Minute	DIAMETER OF SHAFT									
	1"	1 1/16"	1 1/8"	1 3/16"	1 1/4"	1 5/16"	1 3/8"	1 7/16"	1 1/2"	1 9/16"
1	.0091 .0116 .0148	.0184 .0235 .0302	.0330 .0416 .0535	.0530 .0670 .0860	.0800 .1020 .1310	.1150 .1470 .1880	.1590 .2030 .2610	.2140 .2720 .3500	.2790 .3550 .4560	.3560 .4530 .5830
20	.18 .23 .30	.37 .50 .60	.65 .83 1.07	1.1 1.4 1.7	1.6 2.0 2.6	2.3 2.9 3.8	3.2 4.1 5.2	4.3 5.4 7.0	5.6 7.1 9.1	7.1 9.1 11.7
40	.36 .46 .59	.73 .94 1.21	1.3 1.7 2.1	2.1 2.7 3.5	3.2 4.1 5.2	4.6 5.9 7.5	6.4 8.1 10.4	8.5 10.9 14.0	11.2 14.2 18.2	14.2 18.1 23.3
60	.54 .69 .89	1.1 1.4 1.8	2.0 2.5 3.2	3.2 4.0 5.2	4.8 6.1 7.9	6.9 8.8 11.3	9.6 12.2 15.6	12.8 16.3 21.0	16.7 21.3 27.4	21.4 27.2 35.0
80	.73 .92 1.19	1.5 2.0 2.4	2.6 3.3 4.3	4.2 5.4 6.9	6.4 8.2 10.5	9.2 11.7 15.1	12.7 16.2 20.9	17.1 21.8 28.0	22.3 28.4 36.5	28.5 36.2 46.6
100	.91 1.15 1.48	1.8 2.3 3.0	3.3 4.2 5.4	5.3 6.7 8.7	8.0 10.2 13.1	11.5 14.7 18.8	15.9 20.3 26.1	21.4 27.2 34.9	27.9 35.5 45.6	35.6 45.3 58.3
120	1.1 1.4 1.8	2.2 2.8 3.6	3.9 5.0 6.4	6.3 8.1 10.4	9.6 12.2 15.7	13.8 17.6 22.6	19.1 24.3 31.3	25.6 32.6 41.9	33.5 42.6 54.7	42.7 54.4 70.0
140	1.3 1.6 2.1	2.6 3.3 4.2	4.6 5.8 7.5	7.4 9.4 12.1	11.2 14.3 18.3	16.1 20.5 26.4	22.3 28.4 36.5	29.9 38.1 48.9	39.1 49.7 63.8	49.8 63.4 81.6
160	1.5 1.9 2.4	3.0 3.8 4.8	5.2 6.7 8.6	8.5 10.8 13.8	12.8 16.3 21.0	18.4 23.5 30.1	25.5 32.4 41.7	34.2 43.5 55.9	44.6 56.8 73.0	57.0 72.5 93.3
180	1.6 2.1 2.7	3.3 4.2 5.4	5.9 7.5 9.6	9.5 12.1 15.6	14.4 18.3 23.6	20.7 26.4 33.9	28.7 36.5 46.9	38.4 49.0 62.9	50.3 63.9 82.1	64.1 81.5 104.9
200	1.8 2.3 3.0	3.7 4.7 6.0	6.5 8.2 10.7	10.7 13.5 17.3	16.0 20.4 26.2	23.0 29.3 37.7	31.9 40.6 52.1	42.7 54.4 69.9	55.8 71.0 91.2	71.2 90.6 116.6
210	1.9 2.4 3.1	3.9 4.9 6.3	6.9 8.7 11.2	11.2 14.1 18.2	16.8 21.4 27.5	24.2 30.8 39.6	33.5 42.6 54.7	44.8 57.1 73.4	58.6 74.6 95.8	84.8 95.1 122.4
220	2.0 2.5 3.3	4.1 5.2 6.6	7.2 9.2 11.8	11.7 14.8 19.0	17.6 22.4 28.8	25.3 32.2 41.5	35.1 44.6 57.4	47.0 59.8 76.9	61.4 78.1 100.3	88.3 99.7 128.3
230	2.1 2.7 3.4	4.2 5.4 6.9	7.5 9.6 12.3	12.3 15.5 19.9	18.4 23.4 30.1	26.5 33.7 43.3	36.6 46.6 60.0	49.1 62.6 80.4	64.2 81.7 104.9	91.9 104.2 134.1
240	2.2 2.8 3.6	4.4 5.6 7.2	7.8 10.0 12.8	12.8 16.2 20.8	19.2 24.4 31.4	27.6 35.2 45.2	38.2 48.7 62.6	51.2 65.3 83.9	67.0 85.2 109.4	95.4 106.7 139.9
250	2.3 2.9 3.7	4.6 5.9 7.5	8.2 10.4 13.4	13.3 16.8 21.6	20.0 25.5 32.8	28.8 36.6 47.1	39.8 50.7 65.2	53.4 68.0 87.4	69.8 88.8 114.0	99.0 113.3 145.7
260	2.4 3.0 3.9	4.8 6.1 7.8	8.5 10.8 13.9	13.8 17.5 22.5	20.8 26.5 34.1	29.9 38.1 49.0	41.4 52.7 67.8	55.5 70.7 90.8	72.5 92.3 118.6	103. 118. 152.
270	2.5 3.1 4.0	4.9 6.3 8.1	8.8 11.2 14.4	14.4 18.2 23.4	21.6 27.5 35.4	31.1 39.6 50.9	43.0 54.7 70.4	57.7 73.4 94.3	75.3 95.9 123.1	106. 122. 157
280	2.5 3.2 4.2	5.2 6.6 8.4	9.2 11.6 15.0	14.9 18.8 24.2	22.4 28.5 36.7	32.2 41.0 52.8	44.6 56.8 73.0	59.8 76.2 97.8	78.1 99.4 127.7	110. 127. 163.
290	2.6 3.4 4.3	5.3 6.8 8.7	9.5 12.1 15.5	15.4 19.5 25.1	23.2 29.5 38.0	33.4 42.5 54.6	46.2 58.8 75.6	61.9 78.9 101.3	80.9 103.0 132.2	113. 131. 169.
300	2.7 3.5 4.5	5.5 7.0 9.0	9.8 12.5 16.0	16.0 20.2 26.0	24.0 30.5 39.3	34.5 44.0 56.5	47.8 60.8 78.2	64.1 81.6 104.8	83.7 106.5 136.8	117. 136. 175.

Revolutions Per Minute	DIAMETER OF SHAFT									
	1 5/8"	1 11/16"	1 3/4"	1 13/16"	1 7/8"	1 15/16"	2"	2 1/16"	2 1/8"	2 3/16"
1	.4470 .5890 .7310	.5510 .7020 .9020	.6710 .8550 1.1000	.8060 1.0290 1.3220	.961 1.223 1.573	1.133 1.442 1.854	1.324 1.685 2.167	1.535 1.954 2.513	1.768 2.250 2.894	2.023 2.576 3.311
20	8.9 11.4 14.6	11.0 14.0 18.1	13.4 17.1 22.0	16.2 20.6 26.4	19.2 24.5 31.5	22.7 28.8 37.1	26.5 33.7 43.3	30.7 39.1 50.3	35.4 45.0 57.9	40.5 51.5 66.2
40	17.9 22.8 29.2	22.1 28.1 36.1	26.9 34.2 44.0	32.2 41.1 52.9	38.4 48.9 62.9	45.3 57.7 74.2	53.0 67.4 86.7	61.4 78.2 100.5	70.7 90.0 115.7	81.0 103.0 133.4
60	26.8 34.1 43.9	33.1 42.1 54.2	40.3 51.3 66.0	48.5 61.7 79.3	57.7 73.4 94.4	68.0 86.5 111.2	79.5 101.1 130.0	92.1 117.3 151.0	106. 135. 174.	120. 155. 199.
80	35.8 45.5 58.5	44.1 56.2 72.2	53.7 68.4 87.9	64.6 82.2 105.7	76.9 97.8 125.8	90.6 115.3 148.3	106. 135. 173.	123. 156. 201.	142. 180. 233.	162. 206. 265.
100	44.7 56.9 71.1	55.2 70.2 90.3	67.2 85.5 110.0	80.8 102.8 132.2	96.1 122.3 157.3	113. 144. 185.	133. 169. 217.	154. 195. 251.	177. 225. 289.	202. 258. 331.
120	53.6 68.3 87.7	66.2 84.2 108.3	80.6 102.6 131.9	96.9 123.3 158.6	115. 147. 189.	136. 173. 223.	159. 202. 260.	184. 235. 302.	212. 270. 347.	243. 309. 397.
140	62.6 79.7 102.3	77.2 98.3 126.3	94.0 119.6 153.8	113. 144. 185.	135. 171. 220.	159. 202. 260.	186. 236. 303.	215. 274. 353.	248. 315. 405.	283. 361. 464.
160	71.5 91.0 117.0	88.2 115.3 144.4	107. 137. 176.	129. 165. 212.	154. 196. 252.	181. 231. 297.	212. 270. 347.	246. 313. 403.	283. 360. 463.	324. 413. 530.
180	80.5 102.4 131.6	99.3 126.3 162.4	121. 154. 198.	145. 185. 238.	173. 220. 283.	204. 260. 334.	239. 303. 390.	276. 352. 452.	318. 405. 521.	364. 464. 596.
200	89.4 113.8 146.2	110. 140. 181.	134. 171. 220.	162. 206. 264.	192. 245. 314.	227. 288. 371.	265. 337. 433.	307. 391. 503.	354. 450. 579.	405. 515. 662.
210	93.9 119.5 153.5	116. 147. 190.	141. 180. 231.	170. 216. 278.	202. 257. 330.	238. 303. 389.	278. 354. 455.	323. 410. 528.	371. 473. 608.	425. 541. 695.
220	98.3 125.2 160.8	121. 154. 199.	148. 189. 242.	178. 226. 291.	211. 269. 346.	249. 317. 408.	291. 371. 477.	338. 430. 553.	389. 495. 637.	445. 567. 729.
230	103. 131. 168.	127. 161. 208.	154. 197. 253.	186. 236. 304.	221. 281. 362.	261. 332. 426.	305. 388. 499.	353. 450. 578.	407. 518. 666.	466. 593. 763.
240	107. 137. 175.	132. 169. 217.	161. 205. 264.	194. 247. 318.	231. 294. 378.	272. 346. 445.	318. 405. 520.	369. 469. 603.	424. 540. 695.	486. 619. 795.
250	112. 142. 183.	138. 176. 226.	168. 214. 275.	202. 257. 330.	240. 306. 393.	283. 361. 464.	331. 421. 542.	384. 489. 628.	442. 563. 723.	506. 644. 828.
260	116. 148. 190.	143. 183. 235.	175. 222. 286.	210. 267. 344.	250. 318. 409.	295. 375. 482.	344. 438. 564.	399. 508. 653.	460. 585. 752.	526. 670. 861.
270	121. 154. 198.	149. 190. 244.	181. 231. 297.	218. 278. 357.	260. 330. 425.	306. 389. 501.	358. 455. 585.	415. 528. 678.	478. 608. 781.	546. 695. 894.
280	125. 159. 205.	154. 197. 253.	188. 239. 308.	226. 288. 370.	269. 343. 440.	317. 404. 519.	371. 472. 607.	430. 547. 704.	495. 630. 810.	567. 721. 927.
290	130. 165. 212.	160. 204. 262.	195. 248. 319.	234. 298. 383.	279. 355. 456.	329. 418. 535.	384. 489. 629.	445. 567. 729.	513. 653. 839.	588. 747. 960.
300	134. 171. 219.	166. 211. 271.	202. 256. 330.	242. 308. 397.	288. 367. 472.	340. 433. 556.	397. 506. 650.	461. 586. 754.	531. 676. 868.	608. 773. 994.

Horsepower Transmitted by Turned Steel Shafting

These three tables show the power which may be transmitted by turned steel shafting under various operating conditions and can be used to check the size of lineshaft required. The figures in these tables of horsepower, in their respective order, are based upon the following formula:

Heavy or main shafting: $0.011 \times d^3 \times N$
Shafting carrying gears: $0.014 \times d^3 \times N$
Light shafts carrying pulleys only: $0.018 \times d^3 \times N$
d = *Diameter of shaft*
N = *Number of rev. per minute*

In computing these tables the torsional strength allowed in using the above formula is 3,530 lb., 4,490 lb., and 5,770 lb. respectively. The line of figures in the column for 1 r.p.m. gives the horsepower transmitted by any of the given sizes of shafts at a speed of 1 r.p.m. The horsepower at any other speed can be ascertained by multiplying the horsepower at 1 r.p.m. by the number of r.p.m. desired. In case it should be desired to know the amount of power transmitted by any size of lineshaft at a greater speed than is shown by the table, divide the desired speed by 10 to reduce it to a speed as shown in the table. Then multiply the power shown in the table for the speed reduced by 10 and it will show the power at the desired speed. For example, on a shaft running 800 r.p.m., what power will be transmitted by a 3 3/16-in. heavy shaft? Dividing 800 r.p.m. by 10 gives 80 r.p.m. A 3 3/16-in. shaft running 80 r.p.m. will transmit 28.5 hp., according to the table. Multiplying by 10 gives 285 horsepower. This can be safely transmitted by a 3 3/16-in. shaft running at 800 r.p.m., if properly installed and supported.

It is sometimes necessary to make additional allowance for power transmitted in case shock load, such as punch presses, or shears, or machines operated by clutches, is a part of the line. In such cases, it is customary to increase the horsepower assumed as required for operating the equipment in some cases as much as two or three times to take care of this additional loading.

Revolutions Per Minute	DIAMETER OF SHAFT									
	5 1/8"	6 1/2	7	7 1/2	8	8 1/2	9	10	11	12
1	2.302 2.930 3.768	3.02 3.84 4.94	3.77 4.80 6.17	4.64 5.91 7.60	5.63 7.17 9.22	6.76 8.60 11.05	8.02 10.20 13.10	11.00 14.00 18.00	14.64 18.62 23.90	19.00 24.20 31.10
20	46.1 58.6 75.3	60.4 76.9 98.8	75.5 96.0 123.0	92.8 118.0 152.0	113. 143. 184.	135. 173. 223.	160 204. 262.	220. 280. 360.	293. 373. 479.	380. 484. 622.
40	92.1 117.2 150.7	121. 154. 198.	151. 192. 247.	185. 236. 304.	225. 287. 368.	270. 344. 466.	321. 408. 525.	440. 560. 720.	585. 745. 958.	760. 967. 1244.
60	138. 176. 226.	181. 231. 297.	226. 288. 370.	278. 354. 456.	340. 430. 553.	405. 516. 699.	481. 612. 787.	660. 840. 1080.	878. 1118. 1437.	1140. 1451. 1866.
80	184. 234. 301.	242. 308. 395.	301 384. 494.	371 472. 608.	450. 573. 737.	540. 688. 932.	641. 816. 1049.	880. 1120. 1240.	1171. 1490. 1916.	1520. 1935. 2488.
100	230. 293. 377.	302. 385. 494.	377. 480. 617	464 590. 760.	563. 717. 921.	675. 860. 1105.	802. 1020. 1312.	1100. 1400. 1800.	1464. 1863. 2396.	1900. 2419. 3110
120	276. 352. 452.	362. 461. 593.	452. 576. 741.	557. 708. 912.	675. 860. 1105.	810. 1032. 1398.	962. 1224. 1574.	1320. 1680. 2160.	1756. 2236. 2875.	2280. 2903. 3732.
140	322. 410. 528.	423 538. 692.	528. 672. 864.	649. 826. 1064.	788. 1004. 1289.	945. 1204. 1631.	1123. 1428. 1837.	1540. 1960. 2520.	2049. 2609. 3354.	2660. 3386. 4354.
160	368. 469. 603.	483. 615. 791.	603. 768. 988.	742. 944. 1216.	900. 1147. 1473.	1081. 1376. 1864.	1283. 1632. 2099.	1760. 2240. 2880.	2342. 2981. 3833.	3040. 3870. 4976.
180	414. 527. 678.	544. 692. 890.	679. 864. 1111	835 1062. 1368.	1013. 1290. 1658.	1216. 1548. 2097.	1443. 1836. 2361.	1980. 2520. 3240.	2635. 3354. 4312.	3420. 4354. 5598.
200	461 586. 754.	604. 769. 988.	755. 960. 1235.	928. 1181. 1520.	1126. 1434. 1842.	1351. 1720. 2330.	1604. 2040. 2624.	2200 2800. 3600.	2928. 3727. 4792.	3800. 4838. 6230.
210	484. 615. 791.	634. 807. 1038.	792. 1006. 1296.	974. 1240. 1595.	1182. 1505. 1934.	1418. 1806. 2446.	1684. 2142. 2755.	2310. 2940. 3780.	3074. 3913. 5031.	3990. 5080. 6531.
220	507. 645. 829.	664. 845. 1087.	830. 1056. 1358.	1020. 1299. 1672.	1238. 1577. 2026.	1485. 1892. 2563.	1764. 2244. 2886.	2420. 3080. 3960.	3220. 4100. 5270.	4180. 5322. 6842.
230	530. 674. 867.	695. 884. 1137.	867. 1104. 1420.	1067. 1358. 1748.	1295. 1649. 2118.	1553. 1978. 2680.	1845. 2346. 3017.	2530. 3220. 4140.	3367. 4285. 5510.	4370. 5564. 7183.
240	553. 703. 904.	725. 922. 1186.	905. 1152. 1481.	1114. 1417. 1824.	1351. 1720. 2210.	1621. 2064. 2796.	1925. 2448. 3149.	2640. 3360. 4320.	3513. 4473. 5750.	4560. 5806. 7464.
250	576. 733. 942.	755. 961. 1236.	943. 1200. 1543.	1160. 1476. 1900.	1407. 1792. 2302.	1688. 2150. 2913.	2005. 2550. 3280.	2750. 3500. 4500.	3660. 4655. 5990.	4750. 6048. 7775.
260	599. 762. 980.	785. 1000. 1285.	981. 1248. 1605.	1206. 1535. 1976.	1464. 1864. 2394.	1756. 2236. 3029.	2085. 2653. 3411.	2860. 3640. 4680.	3806. 4844. 6229.	4940. 6290. 8086.
270	622. 791. 1017.	815. 1038. 1334.	1018. 1296. 1667.	1252. 1594. 2052.	1520. 1935. 2487.	1824. 2322. 3145.	2165. 2754. 3542.	2970. 3780. 4860.	3953. 5031. 6468.	5130. 6532. 8397.
280	645. 821. 1055.	845. 1079. 1384.	1056. 1344. 1728.	1300. 1653. 2128.	1576. 2007. 2579.	1891. 2406. 3263.	2245. 2855. 3673.	3080. 3920. 5040.	4100. 5217. 6706.	5320. 6773. 8708.
290	668. 850. 1093.	876. 1115. 1433.	1094. 1392. 1790.	1345. 1712. 2204.	1632. 2079. 2671.	1959. 2494. 3378.	2326. 2958. 3805.	3190. 4060. 5220.	4245. 5403. 6948.	5510. 7015. 9019.
300	691. 879. 1130.	906. 1153. 1483.	1133. 1440. 1853.	1392. 1771. 2280.	1689. 2150. 2764.	2026. 2580. 3495.	2406. 3060. 3936.	3300. 4200. 5400.	4392. 5590. 7187.	5700. 7257. 9330.

ting. Ordinarily, shafts longer than 22 ft. do not go into an ordinary box car and so there is often some delay in shipping such bars by rail on account of the necessity of providing special cars. Because of the difficulty in handling, the long bars are more often bent in shipment, especially when shafts are shipped with flanges attached.

The best length of shaft to use varies somewhat with the way the shaft is to be hung. It is usually best to use a shaft of such length that at least two hangers will be included in each length of shaft. For example, if the hangers are spaced 8 ft. apart a 16-ft. shaft would be used, while if spaced 10 ft. apart, a 20-ft. shaft would be required. Shafts can be obtained up to 40 ft. on special order and at an extra price.

The stresses to which lineshafting are mainly subject are, torsion or twisting, and transverse or bending stresses. The torsional strength or resistance to breaking by twisting is directly proportional to the cube of the diameter of the shaft. The torsional stiffness which determines the angle through which the shaft is twisted varies directly as the fourth power of the diameter and inversely as the length of the shaft.

The transverse strength or resistance to bending as a beam is directly proportional to the cube of the diameter and inversely proportional to the length between supports or bearings. The transverse stiffness which determines the deflection or bending of the shaft, considered as a beam, is directly proportional to the fourth power of the diameter, and is inversely proportional to the load and to the cube of the distance between the supports.

It is a somewhat complicated problem to work out mathematically the exact size of a lineshaft. The accompanying tables, however, show the power which may be transmitted by a lineshaft under three classes of service. In general the speed of the shaft is determined in advance by operating conditions. In determining the load on a shaft, care must be exercised to see that proper allowance is made for shock loads and clutches.

Also, one of the practical difficulties in industrial installations lies in the fact that due to the frequent changes, rearrangements and the addition of machines it is always best to provide a shaft of at least slightly above absolutely required size so that it would always be able to take care of these additions or changes. In the arrangement of machines, wherever possible, it is best to provide the heaviest load, and particularly machines which give a shock load, as near as possible to the driving mechanism so that the twisting or torsion load of the shock will not be transmitted

These Articles Contain Other Information on Transmission Equipment

Ball and Roller Bearings—Page 420, Sept. 1922.

Types and Sizes of Pulleys—Page 519, Nov. 1922.

Pulley Service and Long Life—Page 575, Dec. 1922.

Use of Gears and Pinions—Page 81, Feb. 1923.

Gears and Speed Reducers—Page 131, March 1923.

Fabric-Base and Leather Belts—Page 147, March 1923.

Operating Conditions Affecting Belt Service—Page 189, April 1923.

Servicing Industrial Belts—Page 236, May 1923.

Reclaiming Leather Belts—Page 304, June 1923.

Types and Kinds of Chain Drives—Page 335, July 1923.

Operating Conditions Affecting Chain Service—Page 379, Aug. 1923.

How Chain Drives Have Reduced Production Losses—Page 432, Sept. 1923.

Use of Rigid and Compression Couplings—Page 499, Oct. 1923.

Types and Kinds of Flexible Couplings—Page 529, Nov. 1923.

Installation and Operation of Flexible Couplings—Page 579, Dec. 1923.

Uses of Clutch and Cutoff Couplings—Page 51, Jan. 1924,

Trends and Practices in the Use of Mechanical Devices in the Path of Power Service—Page 61, Feb. 1924.

When to Use Group and Individual Drives—Part I, Page 56, Feb. 1924; Part II, Page 118, March 1924; Part III, Page 174, April 1924.

Operating Clutches and Cutoff Couplings—Page 127, March 1924.

Sleeve Bearing Troubles—Page 113, March 1924.

Roller Bearing Service—Page 164, April 1924.

Three types of pressed-steel shaft hangers.

Pressed-steel hangers, because of their lightness, are being used in many light and ordinary installations of power transmission service. The cut-away view shows how one type of hanger is reinforced.

Recommended Sizes for Shafting Key-Stock

Shaft Diameters (Inches) To and Over including	Key Nominal Sizes (Inches) Square Keys W × T	Flat Keys W × T	Key-Stock Sizes (Inches) Square, Square and Flat, Minimum Width S	Minimum Thickness S	F	Tolerances	Square, Square and Flat, Maximum Width S	Maximum Thickness S	F
7/16 — 11/16	1/8	1/8 × 3/32	0.123	0.123	0.092	−0.0020	0.125	0.125	0.094
11/16 — 7/8	3/16	3/16 × 3/32	0.185	0.185	0.154	−0.0020	0.1875	0.1875	0.156
7/8 — 1 3/16	1/4	1/4 × 3/16	0.248	0.248	0.185	−0.0020	0.250	0.250	0.1875
1 3/16 — 1 3/8	5/16	5/16 × 3/16	0.310	0.310	0.185	−0.0020	0.3125	0.3125	0.1875
1 3/8 — 1 11/16	3/8	3/8 × 1/4	0.373	0.373	0.248	−0.0020	0.375	0.375	0.250
1 11/16 — 1 7/8	7/16	7/16 × 5/16	0.435	0.435	0.310	−0.0025	0.4375	0.4375	0.3125
1 7/8 — 2 1/4	1/2	1/2 × 3/8	0.497	0.497	0.373	−0.0025	0.500	0.500	0.375
2 1/4 — 2 3/4	5/8	5/8 × 7/16	0.622	0.622	0.435	−0.0025	0.625	0.625	0.4375
2 3/4 — 3 1/4	3/4	3/4 × 1/2	0.747	0.747	0.497	−0.0025	0.750	0.750	0.500
3 1/4 — 3 3/4	7/8	7/8 × 7/8	0.872	0.872	0.622	−0.0030	0.875	0.875	0.625
3 3/4 — 4 1/2	1	1 × 3/4	0.997	0.997	0.747	−0.0030	1.000	1.000	0.750
4 1/2 — 5 1/2	1 1/4	1 1/4 × 7/8	1.247	1.247	0.872	−0.0030	1.250	1.250	0.875
5 1/2 — 6	1 1/2	1 1/2 × 1	1.497	1.497	0.997	−0.0030	1.500	1.500	1.000

Key sizes for lineshaft work.
The above table shows the recommendation made by the American Society of Mechanical Engineers as to standard sizes for various shaft diameters. These recommendations are out for comment and have not as yet been adopted.

through a long length of shafting. A driving unit at one end and a shock load at the other will result in an uneven transmission of power which is made obvious by the whipping action of belts.

Forged and Special Alloy Shafts for Special Requirements

The largest common commercial size of turned steel shafting is 5 15/16 in. in diameter. Shafts 6 in. or larger are usually made of special forgings. These are made by working an ingot of steel under a steam hammer to a diameter somewhat larger than necessary and then turning it down to an exact diameter in the lathe. In this way, a much stronger shaft is obtained. Also, sections of the forged shafting may be left larger in diameter than other parts. These are made on special order and to dimensions.

Where extra strength, shock resistance, and other unusual requirements are needed for a special installation, nickel steel or vanadium steel shafts are frequently installed. However, the ordinary industrial installation would not require either of these shafts.

Quills or hollow shafts are made from forgings which are later bored out. A quill is used where an extra heavy pulley, sheave or gear is to be installed loose on a line of shafting and connected with a clutch. The advantage of the quill is that the entire weight of this sheave, pulley or gear is supported on the hollow shafting by its own bearing and does not add to the bending load of the lineshaft when it is either idle or running.

Previous articles which have appeared in INDUSTRIAL ENGINEER, as listed in the box on page 181, have discussed the major mechanical elements of power transmission excepting the shafting, hangers, and bearings. Of these, the two latter are intimately connected with the two most important considerations in lineshaft construction and operation—alignment and friction loss.

Some of the Devices Employed for Supporting Lineshafts

In general, hangers differ largely in design according to the purpose for which they are to be used. For example the most common types are: Drop hangers for suspending from the ceiling, floor stands for attaching shafting to the floor, and extensions for post hangers to support the line of shafting at a fixed distance from the wall or from posts. The drop of the hanger—the distance from the base of the hanger to the center of the shaft—often determines the size of pulley which can be used. This, however, depends upon the construction of the building. Frequently drop hangers are used as floor hangers merely by fastening to the floor and inverting the bearings.

An important point in industrial lineshaft construction is to provide sufficient means for adjustment of the shaft. Hangers ordinarily are made with either two- or four-point adjustment, as may be seen from the accompanying illustrations. Four-point, or universal adjustment, gives the greatest opportunity for aligning shafting without having to move the base of the hanger and is being used largely for industrial installations. Two-point adjustment hangers are used for short shafts and for light and comparatively low speed work or for countershafts. To get side adjustment it is necessary to slip the hanger in the slotted base. Obviously it would be more difficult to line up a long shaft and particularly to realign it after it had been used or a building has settled.

Ordinarily, hangers are placed about 8 or 10 ft. apart, depending upon the load and upon the service. Large diameter pulleys, heavy or shock loads, or a heavily loaded pulley, as the driving pulley, often require an extra hanger or closer spacing. Hangers should be close enough to prevent the load from springing (*Continued on page 211*)

Here self-aligning, ball-bearing pillow blocks are installed on each side of a 5-ft. rope sheave. This is connected to a 350-hp. motor by a 6-in. shaft operating at 250 r.p.m.
The pillow blocks are on wedge adjustment plates which provide for up-and-down adjustment. Side adjustments are obtained by screws. Pillow blocks are used on heavy drives and also on many machines.

GOOD INSULATING RESULTS can be easily secured when varnish is given a fair chance on the surfaces to which it is applied. Dirt and lack of care in application are the two things that always cause trouble. On these points Mr. Hazeltine says: Dirty equipment ruins insulation quite as quickly as does faulty application. Wash your brushes or air spray as soon as you are through using them. Clean the varnish tank and strain the varnish at regular intervals. Dirt breeds trouble. Keep your varnish room and apparatus clean.

Suggestions When

Applying Insulating Varnishes

By the Dipping and Baking, Brush and Spraying Or by Vacuum Impregnation Methods

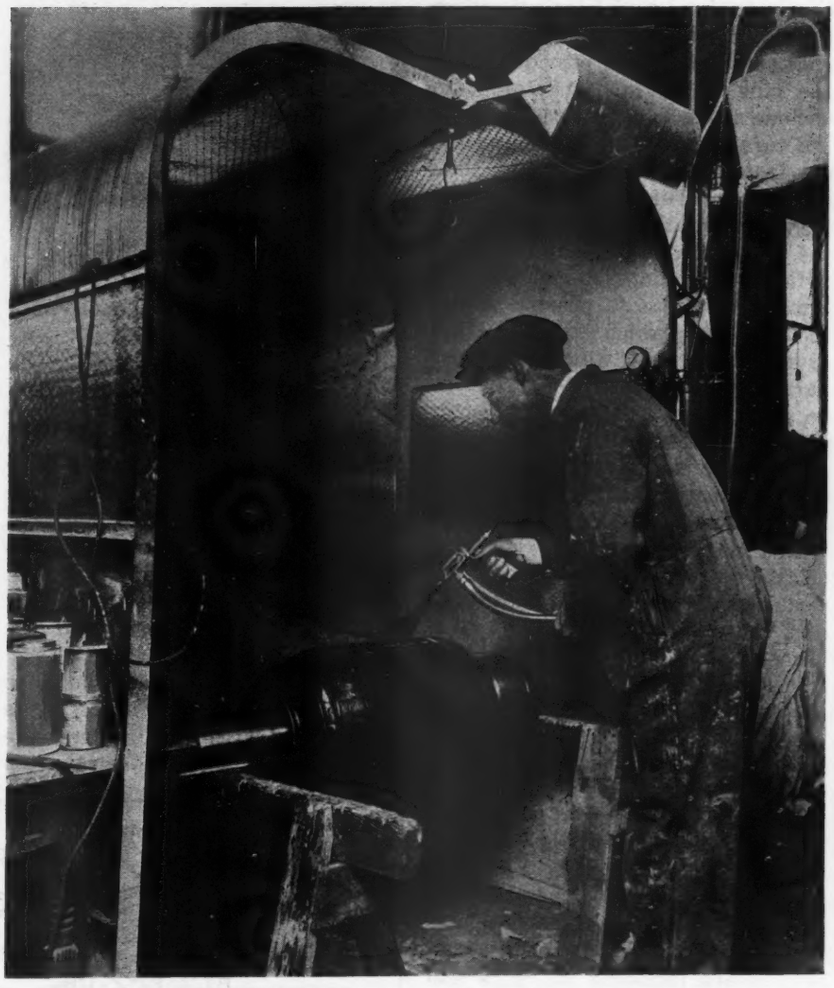
By H. L. HAZELTINE

Engineer of Insulation, The Sterling Varnish Co., Pittsburgh, Pa.

IN THE ARTICLE that appeared in the March issue of INDUSTRIAL ENGINEER, the writer described insulating varnishes in very general terms. In this article the shop equipment necessary for the proper application of these materials will be taken up before going into the detailed methods for securing specific results, in the articles to follow in this series.

Insulating varnishes may be applied by three general methods which, for convenience, will be termed the dipping and baking method, the brushing and spraying method, or the vacuum pressure impregnating method. No matter which method is followed it is important that the apparatus and the surface to which the varnish is applied should be kept very clean. Oily matter or dirt will ruin even the best of insulation.

Perhaps it will be easier to understand the nature of the equipment required if we fix our attention on a coil as it passes through the various processes and describe the apparatus as we go along.



Spraying varnish is preferable to brushing for the finishing application. When ovens are not available it is good practice to dry the coils by passing current through the windings. Oven drying is better, however. The spray-gun shown is made by the De Vilbiss Manufacturing Co., Toledo, Ohio.

APPLICATION OF VARNISH BY DIPPING AND BAKING

The best method of applying insulating varnish is by dipping. The main equipment required for this is a dipping tank and a baking oven. As originally wound, the coil contains a considerable amount of air and moisture which prevents the complete filling with varnish. Hence it should be thoroughly dried in an oven in order to drive out all this moisture and occluded air. The same oven may be used for this preheating period as will be described later for the baking period. The time required for this drying will vary from 1 hr. for coils of small cross section to 24 hrs. for large complete armatures and coils composed of a great many turns of very fine wire.

After preheating, the work is taken directly from the oven and dipped, while still hot, in a tank of varnish and allowed to remain until the varnish has thoroughly permeated the inner layers. As the coil cools, the air remaining in the inside, being rarified, contracts and, assisted by the atmospheric pressure on the surface of the tank, draws the varnish into the interior where insulation and binding strength are most needed.

The Dipping Tank—For this work a tank to hold the varnish will be required of such size and shape that the largest piece to be treated can be completely submerged. It should also be of such capacity that the varnish will not become overheated due to the dipping of hot coils with a consequent loss of solvent. This tank can readily be built in any machine shop, with ⅛-in. steel sheets, which are plenty heavy enough. Do not use a zinc-lined tank because

the zinc has a deleterious effect upon varnish materials. A close fitting cover should be provided when the tank is not in use in order to exclude as much air as possible from the varnish and thus keep the solvent from evaporating. A tank suitable for small-size coils is shown in Fig. 1. Note the groove into which the cover fits. This may be filled with some liquid material such as linseed oil, so as to provide a perfect air seal, which will not evaporate readily and which will not harm the varnish should a few drops be spilled into the tank.

Fig. 1—Dipping tank suitable for small sizes of coils.
Note the groove in which the cover fits, that can be filled with a liquid like linseed oil to provide an air seal.

Large tanks should be fitted with similar covers. When they are of such size that they cannot be handled easily they should be equipped with some means for drawing off the varnish so as to facilitate cleaning. It is surprising how much dirt will collect in a short space of time and how much trouble can be traced directly to varnish that has become fouled as a result. It is impossible to over-emphasize the absolute necessity of frequent thorough cleaning of both varnish and tank.

As the foreign matter which collects in the tank soon becomes mixed with the varnish it is advisable, when the tank has been emptied and cleaned, to strain the varnish through several thicknesses of cambric before replacing it. This will remove all dirt, partially oxidized varnish and pieces of insulation.

Draining—When you are sure that the coils have absorbed all the varnish possible, they should be slowly withdrawn at about the same rate as that at which the varnish flows from the coils of its own accord under the influence of gravity and capillary attraction. This gives a good uniform covering with the least accumulation possible on the one end. When a sufficient number of coils are treated to warrant its use a machine such as is shown in Fig. 2 will be found very useful. The quicker the dip and the faster the rate of withdrawal, the heavier will be the outside coat and the less will be the penetration.

The coil should be allowed to drain for a sufficient period to allow all dripping to cease and for the varnish to partially "set." The time required will again depend upon the size of the coil and the nature of the varnish. When a considerable number of coils are to be treated it is impossible to carry on the entire draining over the tank. Hence it is wise to provide dripping boards over which the coils may be hung, sloped in such a way as to convey the excess varnish back into the tank.

After draining the work should be placed in the oven to bake. It is wise, where possible, to reverse the position of the coil so that the top during draining is at the bottom during baking. The first effect of heat on the partially "set" varnish is to cause it to flow. Hence by reversing the position the heavy accumulation acquired during the draining softens and flows toward the lower end, thus giving a more uniform and pleasing appearance to the finished piece.

The Baking Oven.—The oven required for preheating and baking may be purchased complete from an oven manufacturer, or may be built in the shop. In either case the following suggestions may be helpful.

The outside walls may be constructed of any kind of material desired. It goes without saying that they should be well heat insulated, since the object is to heat the contents of the oven rather than the outside room; an uninsulated surface may be the cause of cold spots and may absolutely prevent an even distribution of temperature throughout the interior of the oven. It is wise, therefore, to build these walls double, filling the air space between

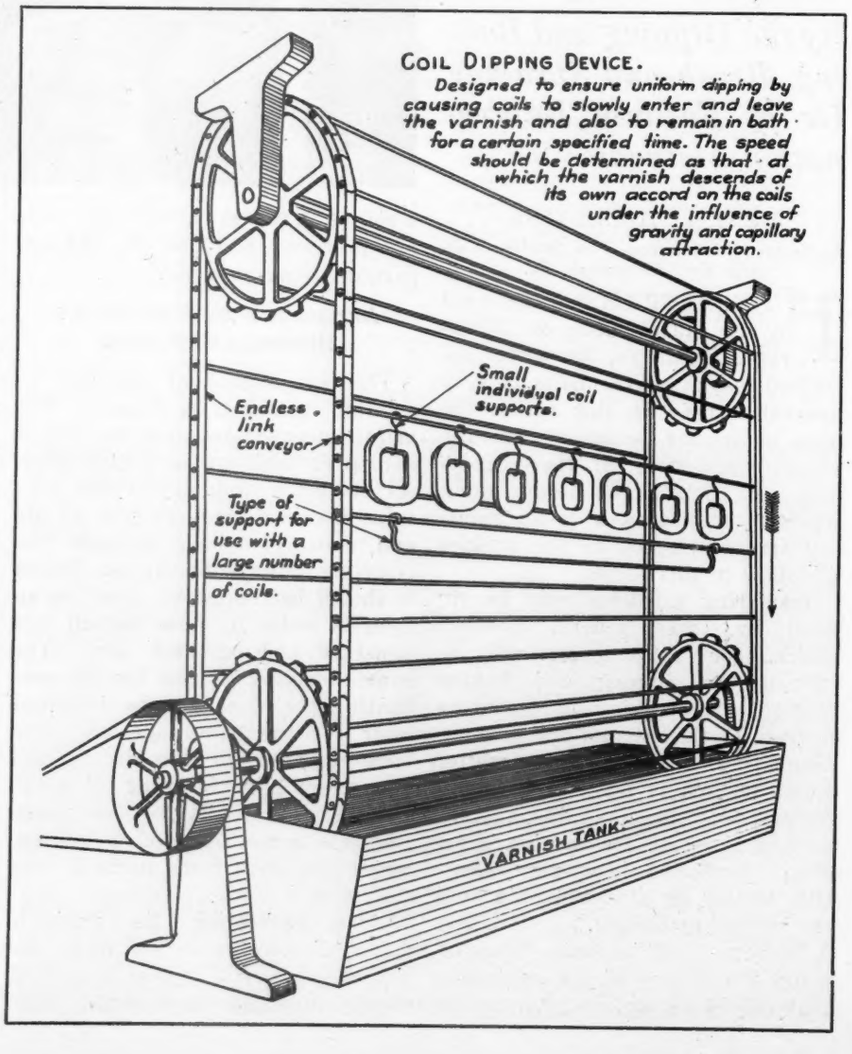

COIL DIPPING DEVICE.
Designed to ensure uniform dipping by causing coils to slowly enter and leave the varnish and also to remain in bath for a certain specified time. The speed should be determined as that at which the varnish descends of its own accord on the coils under the influence of gravity and capillary attraction.
Small individual coil supports.
Endless link conveyor
Type of support for use with a large number of coils.
VARNISH TANK

Fig. 2—Coil dipping machine for use where a large number of coils are treated.

with some loose fibrous material that will serve to break up convection currents in the air and thus prevent the passage of heat from the inner to the outer surface. Further protection may be obtained by completely covering the outer surface with some heat-insulating material. It makes little difference what this material is so long as it is remembered that the less heat that escapes into the room the greater will be the saving in fuel and the more uniform the heat inside.

Many sources of heat may be employed. Those in most common use are gas, steam, oil and electricity. Any one of them will give excellent results provided the oven is properly installed. Indirect or radiant heat is the best.

Gas has the advantage of cheapness. Great care must, however, be taken to see that the burners are so installed that the fumes are conveyed to the chimney without entering the oven where they will come in direct contact with the work. These exhaust fumes tend to combine with the varnish and prevent its baking properly.

Steam is the most satisfactory for baking temperatures up to 300 deg. F. because of its easy regulation and control, its almost universal use for other purposes about the shop and the absence of fire risk.

Oil systems are not in such common use as are the other three. The advantages are much the same as those for steam, with the addition of the ability to obtain very high temperatures without the risk attendant upon the carrying of high steam pressures. The same care must be taken in the installation of the burners as is exercised in the case of gas.

Electric ovens are very efficient and probably the easiest to control. Unless properly built they may be expensive to operate, especially when power is purchased.

Whichever form of heat is chosen great care must be taken in placing the heating units so that they will not interfere with the arrangement of the work in the oven, and so that the temperature will be uniform throughout. Since heated air rises, the heating units should be placed close to the floor so that the bottom part of the oven will have the same temperature as the top. Effective positions are either along the sides or underneath a false bottom. A sufficient amount of radiating surface must be provided so that the temperature required will be reached in the shortest time possible, and thereafter maintained without variation. In very large ovens it is sometimes advisable to install a fan in order to keep the air in motion and prevent the collection of cold pockets.

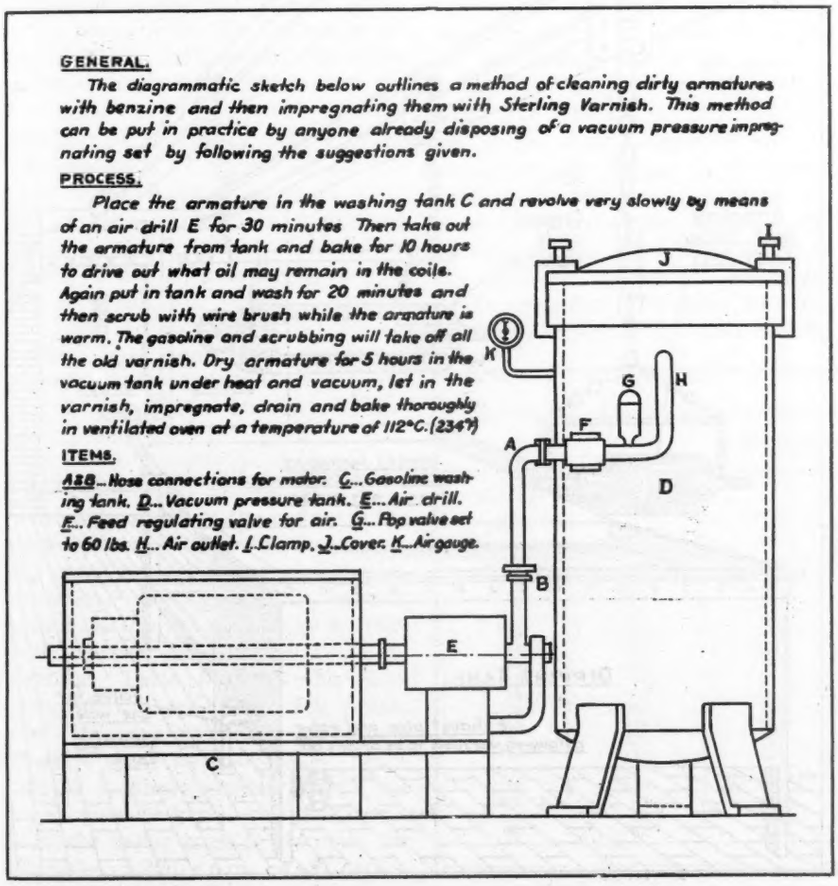
No matter how efficient the heating system, proper drying of the varnish cannot be accomplished as long as it is stewing in the vapor from its own solvent. Hence some means must be used to remove these vapors. In small ovens a direct connection, provided with a damper, to a chimney or a stack is all that is necessary. In large ovens, or those overcrowded with work, forced draft is sometimes required. If, when the doors of the oven are thrown open, a cloud of black smoke pours out into the room, it is evident that you are not carrying away the solvent vapors rapidly enough.

Most baking varnishes are of the oxidizing class and hence a considerable supply of fresh, clean air must always be available. The amount required will depend upon the quantity of work in the oven and the nature of the varnish used. It is better to have too much fresh air than too little. Too much will of course waste the heat, but it is better to do this than to have the varnish only partially dry. It is best to arrange the fresh air inlets in such a position that the entering air strikes the heating units first, so as not to lower the temperature. In small ovens holes drilled through the outside walls will be sufficient. In large ones the blower used to drive the fumes out of the stack may be arranged to draw fresh air into the oven.

Since, in the drying of varnish, the first action of the heat is to drive off the solvent, the damper in the stack should be kept wide open during the initial drying period so as to remove the vapors as quickly as possible. During the later part of the baking, when the solvent has been entirely driven out and the varnish is merely oxidizing, the damper may be partially closed. Care should be taken, however, that it is not shut so tightly that it interferes with the drawing in of the fresh air.

It is important that the temperature of the oven may be known at

Fig. 3—Outfit for cleaning armatures and impregnating them with varnish.


GENERAL.
The diagrammatic sketch below outlines a method of cleaning dirty armatures with benzine and then impregnating them with Sterling Varnish. This method can be put in practice by anyone already disposing of a vacuum pressure impregnating set by following the suggestions given.
PROCESS.
Place the armature in the washing tank C and revolve very slowly by means of an air drill E for 30 minutes. Then take out the armature from tank and bake for 10 hours to drive out what oil may remain in the coils. Again put in tank and wash for 20 minutes and then scrub with wire brush while the armature is warm. The gasoline and scrubbing will take off all the old varnish. Dry armature for 5 hours in the vacuum tank under heat and vacuum, let in the varnish, impregnate, drain and bake thoroughly in ventilated oven at a temperature of 112°C. (234°F)
ITEMS.
A&B...Hose connections for motor. C...Gasoline washing tank. D...Vacuum pressure tank. E...Air drill. F...Feed regulating valve for air. G...Pop valve set to 60 lbs. H...Air outlet. I...Clamp. J...Cover. K...Air gauge.
A
B
C
D
E
F
G
H
I
J
K

any instant. An oven thermometer should therefore be installed. A recording instrument is very convenient for this purpose as then a complete record of the temperature at all times may be obtained. The thermometer bulb should be so placed that the average temperature throughout the oven will be indicated. The proper position may be determined from comparative readings taken in different sections.

Insulating varnishes may be baked at any temperature desired that will not injure the fibrous insulation. The customary range is from 212 deg. F. to 275 deg. F. Of course, the higher the temperature the quicker the drying of the varnish. The lower temperatures have the advantage of drying the varnish all the way through without the formation of a skin over the outside, which tends to retain some of the varnish in a liquid or semi-liquid state. The high temperatures, however, may be used advantageously during the later period of the baking as this not only shortens the drying period but also tends to give a much harder, stronger surface. In preheating the coils it is best, however, to use not over 220 deg. F. The higher temperature is not needed to drive out the moisture and tends to evaporate too much of the solvent in the varnish when the coils are dipped hot.

When lack of space prevents the installation of such baking arrangements as have been described, an individual oven may be built. This can be made of a metal box suitably heat insulated and having no bottom. Holes drilled in the top will provide for ventilation and the escape of solvent fumes. Electric heaters fastened to the sides will provide a uniform heat. The coil after treatment may then be laid on the floor, the box placed over it, and the electric heaters connected to the nearest lighting plug.

Apparatus for Cleaning Repair Work—When motor armatures and field coils are brought in for repairs of any kind where complete rewinding is unnecessary, it is the custom in many shops to immerse them in a baking insulating varnish before they are put back into service. This is excellent practice, especially when the motors are subjected to severe conditions or heavy overloads. The varnish penetrates the slot and when dry holds the armature coils in place, even when the insulation has dried out so much in service that they are quite loose. All cracks are filled up thus preventing the entrance of dirt and moisture. Loose laminations are sealed and their vibration prevented. A rust-proof coating is formed over all iron parts. A smooth, dense insulating surface is formed on coils and on creepage surfaces. Vital parts which have been bruised in handling or in which the insulation has been cracked by strains in service or assembly will be completely restored to good condition. The glossy surface produced will prevent the action of water, etc., where the field coils are connected and taped and will allow dirt to be periodically blown off with an air blast.

These armatures and coils are generally very dusty and oftentimes covered with oil when they are brought in. This accumulation must be removed before the parts are dipped in order not to foul the varnish, and also in order that the varnish may adhere to the surfaces. If dust alone is present it may be removed by blowing with compressed air. A good arrangement is to fit up a closed box so that the armature or coil may be placed inside and an air hose connected near the bottom so as to blow the compressed air into the box. From the top there should be a pipe connecting with the outside air so that the dust and dirt will be blown directly outdoors without entering the room.

If there is considerable grease or oil on the coils it can best be removed by washing in gasoline or benzine. Apparatus suitable for this work is pictured in Fig. 3. The operation is as follows: Place the armature in the oven and bake for 10 hr. or until the coils and core are warmed clear through. Remove from the oven and place in the washing tank *C* filled with gasoline, and revolve very slowly by means of an air control or electric motor *E* for 30 min. This will remove most of the dirt and oil. It would be wise after this process to bake the armature again in order to drive out the gasoline (*Continued on page 209*)

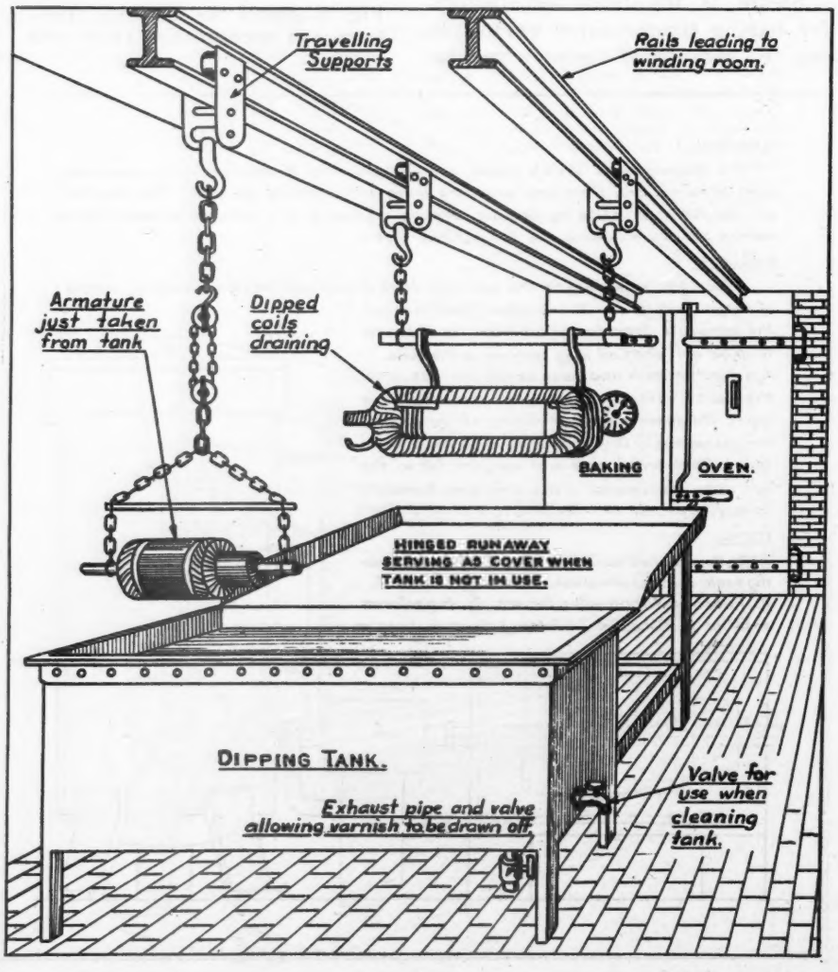

Travelling Supports
Rails leading to winding room.
Armature just taken from tank
Dipped coils draining
BAKING OVEN.
HINGED RUNAWAY SERVING AS COVER WHEN TANK IS NOT IN USE.
DIPPING TANK.
Exhaust pipe and valve allowing varnish to be drawn off
Valve for use when cleaning tank.

Fig. 4—Dripping, draining and baking arrangements for coils and armatures in a small shop.

Handy Tables For Use When

Changing A. C. Windings for Different Frequencies

And the Practical Ways to Make Such Changes For the Original Speed and Horsepower or for a Different Speed and Horsepower

By A. C. ROE

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QUITE OFTEN it is desired to operate an induction motor on a different frequency than the one for which the motor was originally designed. The following questions then arise: (1) What effect will the new frequency have on the operation of the motor? (2) What changes, if any, are required in the motor windings to insure satisfactory operation on the new frequency? In this article Mr. Roe has worked out in detail the steps to be taken in making various frequency changes and compiled tables that will be useful in this connection.

WHEN changing an induction motor to adapt a design of one frequency for operation on another, mistakes are often made that show up in a change of speed and horsepower that are not suitable for the drive on which the motor is to be used. In this article the writer has listed the practicable changes that can be made and has worked out some examples to show how to make the different changes and secure the desired results. Use is made of tables that the writer has found very convenient in such work.

To begin with, the frequency directly affects the speed of the motor as shown in Table I, which gives the synchronous r.p.m. with different numbers of poles and various cycles. The majority of changes made are from 25 to 60 cycles, 50 to 60, 40 to 60 or *vice versa*. On consulting Table I we find that the no-load speed of a four-pole motor is 750 for 25 cycles, 900 for 30, 1,200 for 40, 1,500 for 50 and 1,800 for 60 cycles. Raising the frequency, therefore, increases the speed in direct proportion and lowering the frequency decreases the speed.

For any frequency changes, the first question to answer is: What will be the speed of the motor on the new frequency and will the resulting speed be satisfactory for the application? As an example, assume that it is desired to change a four-pole, 40-cycle motor for 60-cycle operation. Table I shows the four-pole, 40-cycle speed as 1,200 r.p.m., and the corresponding four-pole, 60-cycle speed as 1,800 r.p.m. Since this is a direct-connected job, the r.p.m. must be kept constant. Therefore, the motor must be rewound for six poles, 1,200 r.p.m. on 60 cycles.

A change in frequency changes the speed in the following proportion: $C \div F = S \div R$ or $R = FS \div C$, where the old frequency equals C, new frequency equals F, old r.p.m. equals S and new speed equals R. Since the windings of an induction motor can be considered the same as in a generator, it follows that the change in speed occasioned by a change in frequency will also affect the line voltage; that is, when a motor is operated at a higher speed higher voltage is required. Likewise, when operated at a lower speed a lower line voltage is required. The voltage then should be varied according to the formula:

$V = FE \div C$, where F and C have the same value as above, E is the old line voltage and V the new line voltage. From this it follows that either the line voltage must be varied in the same proportion and direction as the change in frequency or that the turns per phase or coil must be varied in the same proportion but in the opposite direction to the change in frequency. As an example, consider a 30-cycle, 220-volt, 4-pole, 900-r.p.m. motor that is to be operated on 60 cycles. The new r.p.m. would be 1,800 and the line voltage should be 440 volts, but if it is desired to operate the motor on 220 volts, at 60 cycles, the total turns would have to be reduced one-half.

Another item affected is the horsepower rating of the motor, as Hp. $= (T \times \text{r.p.m.}) \div 5{,}252$, where T equals the torque at one foot radius. If the voltage or turns are varied in the proper amount and direction, the torque will remain practically constant and the horsepower will vary directly as the speed in r.p.m.

From the above remarks, we can now set down the different combinations of changes that are possible.

Change No. 1—With a change in cycles and the line voltage adjusted, the hp. and r.p.m. will vary directly as the frequency and in the same direction.

Table I—Synchronous Speeds With Different Numbers of Poles and Cycles

Number of Poles	Cycles				
	25	30	40	50	60
2	1,500	1,800	2,400	3,000	3,600
4	750	900	1,200	1,500	1,800
6	500	600	800	1,000	1,200
8	375	450	600	750	900
10	300	360	480	600	720
12	250	300	400	500	600
14	214	257	343	428	515
16	187	225	300	375	450
18	166	200	266	333	400
20	150	180	240	300	360
22	136	164	218	273	328
24	125	150	200	250	300
26	115	138	185	230	277
28	107	128	171	214	257
30	100	120	160	200	240
32	94	112	150	187	225
34	88	106	141	176	212
36	83	100	133	166	200

Table II—Multipliers to Use When Raising the Operating Frequency, the Horsepower Varying With the Speed.

Required Change in Cycles	R.P.M.	Hp.	Line Voltage	Circ. Mils.	Turns
25 to 30	1.2	1.2	1.2	1.2	.833
25 to 40	1.6	1.6	1.6	1.6	.625
25 to 50	2.0	2.0	2.0	2.0	.500
25 to 60	2.4	2.4	2.4	2.4	.417
30 to 40	1.33	1.33	1.33	1.33	.750
30 to 50	1.66	1.66	1.66	1.66	.600
30 to 60	2.0	2.0	2.0	2.0	.500
40 to 50	1.25	1.25	1.25	1.25	.800
40 to 60	1.5	1.5	1.5	1.5	.667
50 to 60	1.2	1.2	1.2	1.2	.833

Table III—Multipliers to Use When Lowering the Operating Frequency, the Horsepower Varying With the Speed.

Required Changes in Cycles	R.P.M.	Hp.	Line Voltage	Circ. Mils.	Turns
60 to 25	.417	.417	.417	.417	2.4
60 to 30	.500	.500	.500	.500	2.0
60 to 40	.667	.667	.667	.667	1.5
60 to 50	.833	.833	.833	.833	1.2
50 to 25	.500	.500	.500	.500	2.0
50 to 30	.600	.600	.600	.600	1.667
50 to 40	.800	.800	.800	.800	1.25
40 to 35	.625	.625	.625	.625	1.60
40 to 30	.750	.750	.750	.750	1.33
30 to 25	.833	.833	.833	.833	1.20

Change No. 2—With a change in cycles and poles the speed will be kept nearly constant, the voltage or turns changed to suit the new requirement and the hp. will depend on the speed.

Change No. 3—With a change in cycles and speed, the hp. is kept constant by varying either the line voltage or turns per coil or phase.

Change No. 4—With a change in cycles and poles, the speed is kept as nearly the same as possible, with a constant hp. by varying either line voltage or turns per coil or phase.

In what follows each case will be taken up in turn and a change worked out giving the reasons for each step. This will bring up all the details likely to be encountered in any type of cycle change.

Change No. 1—For the change in cycles only. Tables II and III can be used. In this case the number of poles in the winding will remain the same for both frequencies, but the speed, horsepower, etc., will vary with the cycles. When increasing the speed of a motor, do not run the rotor at a peripheral speed greater than 7,500 feet per minute (peripheral speed equals the diameter of a rotor in feet × 3.1416 × r.p.m.) at the new frequency.

Table II gives the multipliers to use when it is desired to raise the frequency. The first column gives the desired change; that is, 25 cycles to 30 cycles, 40 cycles to 60 cycles, etc. The other five columns indicate the effect of the change on the r.p.m., horsepower, line voltage, area in circ. mils or the cross section of copper per coil, and the turns per coil or phase.

For example, consider a 25-cycle, 10-hp., 4-pole, 220-volt, 3-phase, 750-r.p.m. motor which is to be changed to 60 cycles. On consulting Table II, and the 25- to 60-cycle line, we find that the r.p.m. will increase 2.4 times or 750 × 2.4 equals 1,800 r.p.m. The horsepower rating would then be 10 × 2.4 or 24, but to obtain this rating and to keep the torque and other electrical conditions in the motor the same, the line voltage will have to be increased to 2.4 × 220 or 528 volts. In most cases the line voltage must remain the same; then the turns per coil or phase must be changed as shown in the last column. In this case, the turns will have to be decreased. If the motor had ninety turns per phase on 25 cycles it should have 90 × .417 or 37½ turns on 60 cycles. The turns might be decreased by reconnecting in some cases, and the voltage brought to within 10 per cent of the required value, or the stator would have to be rewound. In case of either reconnection or rewinding, the cross section of copper must also be changed at the same time and by the amount indicated in the tables.

It will be noticed when studying the tables, that whenever the line voltage is raised, the table indicates that the same results can be obtained by decreasing the turns and that when the turns are decreased, the area of copper should be increased and *vice versa*. The following details refer to the table of possible changes at the top of this page.

Table III gives the values when the frequency is to be lowered. This table shows that the r. p. m. and horsepower will decrease, but in any case where the speed is reduced the maximum horsepower rating should be at least five per cent lower than the value given. This is due to the lessened ventilation at lower speeds.

The above is the simplest frequency change. A close study of Tables II and III will indicate what the effect on the performance of the

Table IV—Multipliers to Use When Changing the Cycles and Poles with Horsepower Also Changed

Change From	Poles	R.P.M.	Hp	Line Voltage	Circ. Mils.	Turns
2-Pole, 25-cycl to 60-cycle	4	1.2	1.2	1.2	1.2	0.833
	6	0.80	0.80	0.80	0.80	1.25
	8	0.60	0.60	0.60	0.60	1.667
	10	0.48	0.48	0.48	0.48	2.08
	12	0.40	0.40	0.40	0.40	2.50
4-Pole, 25-cycle to 60-cycle	2	4.80	4.80	4.80	4.80	0 208
	6	1.60	1.60	1.60	1.60	0 625
	8	1.20	1.20	1.20	1.20	0 833
	10	0.96	0.96	0.96	0.96	1.042
	12	0.80	0.80	0.80	0.80	1.25
6-Pole, 25-cycle to 60-cycle	2	7.20	7.20	7.20	7.20	0.139
	4	3.60	3.60	3.60	3.60	0 278
	8	1.80	1.80	1.80	1.80	0 556
	10	1.44	1.44	1.44	1.44	0 694
	12	1.20	1.20	1.20	1.20	0 833
8-Pole, 25-cycle to 60-cycle	2	9.60	9.60	9.60	9.60	0.103
	4	4.80	4.80	4.80	4.80	0.208
	6	3.20	3.20	3.20	3.20	0.3125
	10	1.92	1.92	1.92	1 92	0 52
	12	1.60	1.60	1.60	1.60	0 625
10-Pole, 25-cycle to 60-cycle	2	12.0	12.0	12.0	12.0	0.833
	4	6.0	6.0	6.0	6.0	0.167
	6	4.0	4.0	4.0	4.0	0 250
	8	3.0	3.0	3.0	3.0	0 333
	12	2.0	2.0	2.0	2.0	0.500
12-Pole, 25-cycle to 60-cycle	2	14.4	14.4	14.4	14.4	0 069
	4	7.2	7.2	7.2	7.2	0 139
	6	4.8	4.8	4.8	4.8	0.208
	8	3.6	3.6	3.6	3.6	0.278
	10	2.88	2.88	2.88	2.88	0.347

motor would be if it were connected to the new line frequency without any change in the winding or line voltage. Consider now a 50 cycle to 60 cycle change. The r.p.m. would be increased 1.2 times, likewise the horsepower, and the line voltage would have to be 1.2 times the 50-cycle voltage, which we will assume as 220. The new or 60-cycle voltage then equals 220 × 1.2 or 264. If the turns were not decreased and the motor put across a 220-volt, 60-cycle line, it would be operating on 83 per cent voltage or under voltage. This would reduce the maximum horsepower rating since the horsepower depends on the torque. Therefore, if the motor is operated on less than the required line voltage, it will develop less torque and consequently less horsepower. If the 50-cycle rating were 25 hp., its rating with correct line voltage on 60 cycles would be 1.2 × 25 equals 30 hp., but with 220 volts on 60 cycles the torque would be $(220 \div 264)^2$ or .69 which is 69 per cent of the 50-cycle torque. Then the 60-cycle rating at 220 volts would be (1.2 × .69 × 25) or 20.7 hp.

To determine what the horsepower rating will be at the new frequency when the turns or line voltage are not changed, the following formula can be used:

$$\text{Hp.} = R \times H \times T \times T.$$

In this, *R* equals the original horsepower rating before changing the cycles, *H* equals the figure under hp., in Tables II or III, and *T* the figure under turns in Tables II and III. In the 50 cycle to 60 cycle change cited above, the formula works out as follows: 25 × 1.2 × .833 × .833 equals 20.7 hp.

From the above it follows that when the frequency is raised and no change made in the turns or line voltage that the horsepower rating will be reduced below the low cycle rating regardless of the increased speed. On the other hand, when the frequency is lowered and no changes are made in the turns or line voltage, the horsepower rating will be increased, even when the figure under the horsepower column in Table III indicates that the horsepower should be lower. For example, consider a 20-hp., 60-cycle, 220-volt motor changed to 30 cycles. Table III shows that the line voltage should be reduced .50 or 50 per cent and that the horsepower will also be reduced, but if the line voltage is left at 220 the rating will be, according to the above formula, 20 × .5 × 2 × 2 equals 40 hp. In this case the heating would be 2.05 times as great as the area of copper is the same and the horsepower doubled and the speed reduced. The motor would then burn out if loaded up to 40 hp.

If it is desired to have the horsepower rating remain the same when changing the frequency, the voltage should be changed as the square

Tables V and VI—Multipliers to Use When Changing from 25 to 50 Cycles and from 25 to 40 Cycles with the Horsepower Also Changed

Change From	Poles	R.P.M. Line Volts Circ. Mils and Hp.	Turns	Change From	Poles	R.P.M. Line Volts Circ. Mils and Hp.	Turns
2-Pole, 25-cycle to 50-cycle	*4	1.0	1.0	2-Pole, 25-cycle to 40-cycle	4	0.800	1.25
	6	0.667	1.5		6	0.533	1.875
	8	0.50	2.0		8	0.400	2.50
	10	0 40	2.5		10	0.320	3.12
	12	0.33	3.0		12	0.267	3.75
4-Pole, 25-cycle to 50-cycle	2	4.0	0.25	4-Pole, 25-cycle to 40-cycle	2	3.20	0.313
	6	1.33	0.75		6	1.07	0.938
	*8	1.0	1.00		8	0.80	1.25
	10	0.80	1.25		10	0.64	1.56
	12	0.667	1.50		12	0.53	1.875
6-Pole, 25-cycle to 50-cycle	2	6.0	0.167	6-Pole, 25-cycle to 40-cycle	2	4.80	0.28
	4	3.0	0.333		4	2.40	0.416
	8	1.5	0.667		8	1.20	0.833
	10	1.2	0.833		10	0.96	1.04
	*12	1.0	1.00		12	0.80	1.25
8-Pole, 25-cycle to 50-cycle	2	8.0	0.125	8-Pole, 25-cycle to 40-cycle	2	6.40	0.156
	4	4.0	0.25		4	3.20	0.313
	6	2.667	0.375		6	2.12	0.47
	10	1.60	0.625		10	1.28	0.78
	12	1.30	0.75		12	1.13	0.937
10-Pole, 25-cycle to 50-cycle	2	10.00	0.10	10-Pole, 25-cycle to 40-cycle	2	8.00	0.125
	4	5.00	0.20		4	4.00	0.250
	6	3.33	0.30		6	2.67	0.375
	8	2.50	0.40		8	2.00	0.500
	12	1.667	0.60		12	1.33	0.75
12-Pole, 25-cycle to 50-cycle	2	12.00	0.083	12-Pole, 25-cycle to 40-cycle	2	9.60	0.104
	4	6.00	0.167		4	4.80	0.208
	6	4.00	0.25		6	3.20	0.313
	8	3.00	0.33		8	2.40	0.416
	10	2.40	0.417		10	1.92	0.520

Tables VII and VIII—Multipliers to Use When Changing from 25 to 30 Cycles and from 30 to 60 Cycles with the Horsepower Also Changed

Change From	Poles	R.P.M. Line Volts Circ. Mils. and Hp.	Turns	Change From	Poles	R.P.M. Line Volts Circ. Mils. and Hp.	Turns
2-Pole, 25-cycle to 30-cycle	4	0.60	1.67	2-Pole, 30-cycle to 60-cycle	*4	1.00	1.00
	6	0.40	2.50		6	0.667	1.50
	8	0.30	3.33		8	0.50	2.00
	10	0.24	4.16		10	0.40	2.50
	12	0.20	5.00		12	0.33	3.00
4-Pole, 25-cycle to 30-cycle	2	2.40	0.416	4-Pole, 30-cycle to 60-cycle	2	4.00	0.25
	6	0.80	1.25		6	1.33	0.75
	8	0.60	1.667		*8	1.00	1.00
	10	0.48	2.68		10	0.80	1.25
	12	0.40	2 50		12	0.667	1.50
6-Pole, 25-cycle to 30-cycle	2	3.60	0.278	6-Pole, 30-cycle to 60-cycle	2	6.00	0.167
	4	1.80	0.556		4	3.00	0.333
	8	0.90	1.111		8	1.50	0.667
	10	0.72	1.39		10	1.20	0.833
	12	0.60	1.667		*12	1.00	1.000
8-Pole, 25-cycle to 30-cycle	2	4.80	0.208	8-Pole, 30-cycle to 60-cycle	2	8.00	0.125
	4	2.40	0.416		4	4.00	0.25
	6	1.60	0.625		6	2.67	0.375
	10	0.96	1.04		10	1.60	0.625
	12	0.80	1.25		12	1.33	0.75
10-Pole, 25-cycle to 30-cycle	2	6.00	0 1667	10-Pole, 30-cycle to 60-cycle	2	10.00	0 10
	4	3.00	0.333		4	5.00	0 20
	6	2.00	0.500		6	3.33	0 30
	8	1.50	0 667		8	2.50	0.40
	*12	1.00	1.000		12	2.30	0.60
12-Pole, 25-cycle to 30-cycle	2	7.20	0.139	12-Pole, 30-cycle to 60-cycle	2	12.0	0 083
	4	3.60	0.278		4	6.0	0 167
	6	2.40	0.416		6	4.0	0 250
	8	1.80	0.556		8	3.0	0 333
	10	1.44	0.722		10	2.4	0 416

*Indicates that the winding can be reconnected and will operate at the same rating on the new frequency. Line voltage in all these tables means the original voltage before making the change in the motor.

root of the cycle change. Consider a change from 25 cycles to 40 cycles. If the voltage is 220 on 25 cycles, changing it to 220 × (40 ÷ 25) equals 220 × 1.264, or 278 volts on 40 cycles will keep the horsepower constant. Table XIV gives the multiple to use for each item when it is desired to make a change and have the horsepower remain constant.

It must be understood that when the *cycles* and speed are changed and the horsepower kept constant, a corresponding change in the cross section of copper must be made by reconnecting or rewinding the stator, as it is seldom possible to obtain such odd voltages as 278 as required in the above case. Then the only remedy is to vary the turns per coil or phase.

Change No. 2—The next change to consider is one where it is desired to change the cycles and keep the speed the same, allowing the horsepower to vary. Tables IV to XII are to be used for this type of change.

Consider a 40 cycle to 50 cycle change, the 40-cycle rating being 25 hp., 220 volts, three-phase, eight-pole, 600 r.p.m. On consulting Table I, 60-cycle column, we find that for 600 r.p.m. on 60 cycles a twelve-pole winding is required. From Table XII and the 40 cycle to 60 cycle change, we find in the 40-cycle, eight-pole section on the twelve-pole, 60-cycle horizontal line that the multiple for the hp., speed, line voltage, turns per phase or coil and circ. mils, is 1. This means that the 40-cycle winding, size of wire and turns is satisfactory for 60 cycles, at the same speed. The only other item requiring checking is the coil pitch. The 40-cycle winding is

Tables IX and X—Multipliers to Use When Changing from 30 to 50 Cycles and from 30 to 40 Cycles with the Horsepower Also Changed

Change From	Poles	R.P.M. Line Volts Circ. Mils. and Hp.	Turns	Change From	Poles	R.P.M. Line Volts Circ Mils and Hp.	Turns
2 Pole,	4	0.833	1.20	2-Pole,	4	0.667	1.50
30-cycle	6	0.555	1.80	30-cycle	6	0.444	2.125
to	8	0.416	2.40	to	8	0.338	3.00
50-cycle	10	0.338	3.00	40-cycle	10	0.267	3.75
	12	0.278	3.60		12	0.222	4.50
4-Pole,	2	3.38	0.30	4-Pole,	2	2.67	0.375
30-cycle	6	1.10	0.90	30-cycle	6	0.89	1.125
to	8	0.833	1.20	to	8	0.667	1.50
50-cycle	10	0.667	1.50	40-cycle	10	0.533	1.875
	12	0.556	1.80		12	0.444	2.25
6-Pole,	2	5.00	0.20	6-Pole,	2	4.00	0.25
30-cycle	4	2.50	0.40	30-cycle	4	2.00	0.50
to	8	1.25	0.80	to	*8	1.00	1.00
50-cycle	*10	1.00	1.00	40-cycle	10	0.80	1.25
	12	0.833	1.20		12	0.667	1.50
8-Pole,	2	6.67	0.15	8-Pole,	2	5.33	0.1875
30-cycle	4	3.38	0.30	30-cycle	4	2.685	0.375
to	6	2.22	0.45	to	6	1.78	0.563
50-cycle	10	1.33	0.75	40-cycle	10	1.06	0 939
	12	1.11	0.90		12	0.89	1.125
10-Pole,	2	8.33	0.12	10-Pole,	2	6.67	0.15
30-cycle	4	4.16	0.24	30-cycle	4	3.38	0.30
to	6	2.78	0.36	to	6	2.22	0.45
50-cycle	8	2.08	0.48	40-cycle	8	1.667	0.60
	12	1.39	0.72		12	1.11	0.90
12-Pole,	2	10.0	0.10	12-Pole,	2	8.00	0.125
30-cycle	4	5.0	0.20	30-cycle	4	4.00	0 25
to	6	3.33	0.30	to	6	2.66	0.375
50-cycle	8	2.50	0.40	40-cycle	8	2.00	0.50
	10	2.00	0.50		10	1.60	0.625

Tables XI and XII—Multipliers to Use When Changing from 40 to 50 Cycles and from 40 to 60 Cycles with the Horsepower Also Changed

Change From	Poles	R.P.M. Line Volts Circ. Mills and Hp.	Turns	Change From	Poles	R.P.M. Line Volts Circ. Mils and Hp.	Turns
2-Pole,	4	0.625	1.60	2-Pole,	4	0.750	1.33
40-cycle	6	0.416	2.40	40-cycle	6	0.500	2.00
to	8	0.313	3.20	to	8	0.375	2.67
50-cycle	10	0.250	4.00	60-cycle	10	0.300	3.33
	12	0.208	4.80		12	0.250	4.00
4-Pole,	2	2.50	0.40	4-Pole,	2	3.000	0.333
40-cycle	6	0.833	1.20	40-cycle	*6	1.000	1.000
to	8	0.625	1.60	to	8	0.750	1.33
50-cycle	10	0.500	2.00	60-cycle	10	0.600	1.667
	12	0.416	2.40		12	0.500	2.000
6-Pole,	2	3.75	0.267	6-Pole,	2	4.50	0.222
40-cycle	4	1.875	0.533	40-cycle	4	2.25	0.444
to	8	0.938	1.07	to	8	1.125	0.89
50-cycle	10	0.750	1.33	60-cycle	10	0.900	1.11
	12	0.625	1.60		12	0.750	1.33
8-Pole,	2	5.000	0.200	8-Pole,	2	6.000	0.167
40-cycle	4	2.50	0.400	40-cycle	4	3.000	0.334
to	6	1.667	0.600	to	6	2.000	0.500
50-cycle	*10	1.000	1.000	60-cycle	10	1.200	0.833
	12	0.833	1.200		*12	1.000	1.000
10-Pole,	2	6.25	0.160	10-Pole,	2	7.500	0.133
40-cycle	4	3.125	0.320	40-cycle	4	3.750	0.266
to	6	2.08	0.480	to	6	2.500	0.400
50-cycle	8	1.56	0.640	60-cycle	8	1.875	0.533
	12	1.04	0.960		12	1.250	0.800
12-Pole,	2	7.50	0.133	12-Pole,	2	9.000	0.111
40-cycle	4	3.75	0.266	40-cycle	4	4.500	0.222
to	6	2.50	0.400	to	6	3.000	0 333
50-cycle	8	1.875	0.533	60-cycle	8	2.250	0 444
	10	1.500	0.667		10	1.800	0.555

*Indicates that the winding can be reconnected and will operate at the same rating on the new frequency.

Table XIII—Multipliers to Use When Changing from 50 to 60 Cycles With the Horsepower Also Changed

Change From	Poles	R. P. M. Line Volts Circ. Mils and Hp.	Turns
2-Pole,	4	0.600	1.667
50-cycle	6	0.400	2.500
to	8	0.300	3.330
60-cycle	10	0.240	4.166
	12	0.200	5.000
4-Pole,	2	2.40	0.416
50-cycle	6	0.80	1.250
to	8	0.60	1.667
60-cycle	10	0.48	2.08
	12	0.40	2.50
6-Pole,	2	3.60	0.278
50-cycle	4	1.80	0.556
to	8	0.90	1.111
60-cycle	10	0.72	1.380
	12	0.60	1.667
8-Pole,	2	4.80	0.208
50-cycle	4	2.40	0.416
to	6	1.60	0.625
60-cycle	10	0.96	1.04
	12	0.80	1.25
10-Pole,	2	6.00	0.1667
50-cycle	4	3.00	0.3334
to	6	2.00	0.5000
60-cycle	8	1.50	0 6667
	*12	1.00	1.0000
12-Pole,	2	7.20	0.138
50-cycle	4	3.60	0.278
to	6	2.40	0.416
60-cycle	8	1.80	0.556
	10	1.44	0.694

*Indicates that the winding can be reconnected and will operate at the same rating on new frequency.

8-pole; there are seventy-two coils and slots, pitch 1-and-8, or two slots under full pitch. The 60-cycle winding requires twelve poles. Pitch for twelve poles should be 72 ÷ 12 equals 6 or 1-and-7 for full pitch. Then as the present coil is 1-and-8, it would be one slot over pitch for the twelve-pole winding, but as over pitch has the same effect as under pitch, the 40-cycle winding can be used without any change being made in the motor. The effect of one slot difference will not affect the performance to any extent.

This change brings up another point that must be considered; that is, the coil pitch, when making a change in the number of poles. The pitch must never be less than 50 per cent of full pitch, and in some cases it might be possible to change the consequent poles by reconnecting 4 to 8, 6 to 12 poles, etc. But when the low pole winding is full pitch, it is impossible to double the poles by reconnecting for consequent poles, as the two halves of the coils in each slot will neutralize each other. For the best results the low pole coil pitch should be 70 to 50 per cent of full pitch as 50 per cent pitch would be 100 per cent or full pitch for twice the number of poles. Therefore, with this type of change it may be necessary to spring the coils back or rewind with new coils to get the proper pitch. When rewinding for a larger or smaller number of poles be sure to use the same percentage of coil pitch in the new winding as was used in the old one.

Tables IV to XII are worth studying as they show a number of possible changes. For instance, Table XII, 40 to 60 cycles, in the 40-cycle, four-pole section we find that at 60 cycles and six poles the hp. etc., is the same. The only item to check is the coil pitch. With the two-pole winding, the hp., etc., will be three times the 40-cycle rating, as it is possible to increase or decrease the rating by the right number of poles on the new frequency.

Consider another speed and cycle change. Take a 30 cycle to 40 cycle change, the 30-cycle rating being 10 hp., 110 volts, two-phase, four-pole, 900 r.p.m. The nearest 40-cycle speed is 800 r.p.m. On the six-pole, 40-cycle line (Table X), we find that the hp. will be 10 × .89 or 8.9 hp. and that the stator will have to be rewound with 1.125 times the 30-cycle turns and .89 times the 30-cycle circ. mils, or if desired, the horsepower could be kept constant as will be explained later.

Change No. 3—Tables IV to XII and XVI to XXV are arranged for

Table XIV—Multipliers to Use When Raising Cycles and Speed with the Horsepower Remaining the Same

Required Change in Cycles	R.P.M.	Hp.	Line Volts	Circ. Mils.	Turns
25 to 30	1.2	1.0	1.099	1.099	.916
25 to 40	1.6	1.0	1.26	1.26	.790
25 to 50	2.0	1.0	1.414	1.414	.707
25 to 60	2.4	1.0	1.55	1.55	.646
30 to 40	1.33	1.0	1.15	1.15	.864
30 to 50	1.66	1.0	1.28	1.28	.771
30 to 60	2.00	1.0	1.414	1.414	.707
40 to 50	1.25	1.0	1.12	1.12	.896
40 to 60	1.50	1.0	1.22	1.22	.813
50 to 60	1.20	1.0	1.099	1.099	.916

Table XV—Multipliers to Use When Lowering Cycles and Speed with the Horsepower Remaining the Same

Required Change in Cycles	R.P.M.	Hp.	Line Volts	Circ. Mils.	Turns
60 to 25	.417	1.0	0.6458	0.6458	1.549
60 to 30	.500	1.0	0.7070	0.7070	1.414
60 to 40	.667	1.0	0.8167	0.8167	1.225
60 to 50	.833	1.0	0.9127	0.9127	1.095
50 to 25	.500	1.0	0.7070	0.7070	1.414
50 to 30	.600	1.0	0.7746	0.7746	1.291
50 to 40	.800	1.0	0.8944	0.8944	1.114
40 to 25	.625	1.0	0.7900	0.7900	1.265
40 to 30	.750	1.0	0.8660	0.8660	1.153
30 to 25	.833	1.0	0.9127	0.9127	1.095

Table XVI—Multipliers to Use When Changing from 25 to 60 Cycles with the Horsepower Remaining the Same

Change From	Poles	R.P.M.	Hp.	Line Volts	Circ. Mils.	Turns
2-Pole, 25-cycle to 60-cycle	4	1.2	1.0	1.099	1.099	0.916
	6	0.80	1.0	0.894	0.894	1.115
	8	0.68	1.0	0.825	0.825	1.213
	10	0.48	1.0	0.693	0.693	1.443
	12	0.40	1.0	0.632	0.632	1.580
4-Pole, 25-cycle to 60-cycle	2	4.80	1.0	2.186	2.186	0.457
	6	1.60	1.0	1.260	1.260	0.790
	8	1.20	1.0	1.099	1.099	0.916
	10	0.96	1.0	0.980	0.980	1.020
	12	0.80	1.0	0.894	0.894	1.118
6-Pole, 25-cycle to 60-cycle	2	7.20	1.0	2.682	2.682	0.373
	4	3.60	1.0	1.898	1.898	0.526
	8	1.80	1.0	1.342	1.342	0.746
	10	1.44	1.0	1.200	1.200	0.833
	12	1.20	1.0	1.099	1.099	0.916
8-Pole, 25-cycle to 60-cycle	2	9.60	1.0	3.100	3.100	0.322
	4	4.80	1.0	2.186	2.186	0.457
	6	3.20	1.0	1.789	1.789	0.558
	10	1.92	1.0	1.386	1.386	0.722
	12	1.60	1.0	1.260	1.260	0.790
10-Pole, 25-cycle to 60-cycle	2	12.00	1.0	3.46	3.46	0.288
	4	6.00	1.0	2.45	2.45	0.408
	6	4.00	1.0	2.00	2.00	0.500
	8	3.00	1.0	1.73	1.73	0.576
	12	2.00	1.0	1.414	1.414	0.707
12-Pole, 25-cycle to 60-cycle	2	14.40	1.0	3.789	3.789	0.263
	4	7.20	1.0	2.682	2.682	0.373
	6	4.80	1.0	2.186	2.186	0.457
	8	3.60	1.0	1.898	1.898	0.526
	10	2.88	1.0	1.698	1.698	0.587

Table XVII—Multipliers to Use When Changing from 25 to 50 Cycles with the Horsepower Remaining the Same

Change From	Poles	R. P. M.	Hp.	Line Volts	Circ. Mils.	Turns
2-Pole 25-cycle to 50-cycle	4	1.0	1.0	1.0	1.0	1.0
	6	0.667	1.0	0.817	0.817	1.225
	8	0.500	1.0	0.707	0.707	1.414
	10	0.400	1.0	0.632	0.632	1.58
	12	0.33	1.0	0.574	0.574	1.74
4-Pole, 25-cycle to 50-cycle	2	0.40	1.0	0.632	0.632	1.58
	6	1.33	1.0	1.153	1.153	0.868
	8	1.00	1.0	1.0	1.0	1.0
	10	0.80	1.0	0.894	0.894	1.115
	12	0.667	1.0	0.817	0.817	1.125
6-Pole, 25-cycle to 50-cycle	2	6.0	1.0	2.45	2.45	0.408
	4	3.0	1.0	1.73	1.73	0.576
	8	1.5	1.0	1.225	1.225	0.816
	10	1.2	1.0	1.099	1.099	0.916
	12	1.0	1.0	1.0	1.0	1.0
8-Pole, 25-cycle to 50-cycle	2	8.0	1.0	2.828	2.828	0.354
	4	4.0	1.0	2.000	2.000	0.500
	6	2.667	1.0	1.634	1.634	0.613
	10	1.60	1.0	1.260	1.260	0.790
	12	1.30	1.0	1.140	1.140	0.877
10-Pole, 25-cycle to 50-cycle	2	10.00	1.0	3.162	3.162	0.316
	4	5.00	1.0	2.236	2.236	0.446
	6	3.33	1.0	1.825	1.825	0.548
	8	2.50	1.0	1.581	1.581	0.633
	12	1.667	1.0	1.292	1.292	0.776
12-Pole, 25-cycle to 50-cycle	2	12.00	1.0	3.460	3.460	0.288
	4	6.00	1.0	2.450	2.450	0.408
	6	4.00	1.0	2.000	2.000	0.500
	8	3.00	1.0	1.732	1.732	0.576
	10	2.40	1.0	1.549	1.549	0.645

use in making a combined cycle and speed change. The first column gives the original cycles, poles two to twelve, and each pole section is divided into five horizontal sections. Each line represents a new pole grouping at the required frequency. It will be noticed that the number of poles used in the first column is not repeated in the second column of the same section. The remaining columns give a multiple to get the required results. In Tables IV to XIII the number in the third column indicates what the speed and horsepower would be at the new cycles and poles, also what the line voltage should be. If the line voltage can not be varied then the turns in the old winding must be varied, according to the fourth column. The circ. mils also change as shown in the proper column. The above also applies to Tables XVI to XXV.

Now consider this third type of change; that is, changing cycles and speed, but the horsepower remaining constant. In order to accomplish this the torque must be increased when the speed is decreased or *vice versa*. This is done by changing the voltage or turns in the correct amount. Tables XIV and XV

Table XVIII—Multipliers to Use When Changing from 25 to 40 Cycles with the Horsepower Remaining the Same

Change From	Poles	R.P.M.	Hp.	Line Volts	Circ. Mils.	Turns
2-Pole, 25-cycle to 40-cycle	4	0.800	1.0	0.894	0.894	1.115
	6	0.533	1.0	0.730	0.730	1.369
	8	0.400	1.0	0.632	0.632	1.580
	10	0.320	1.0	0.566	0.566	1.765
	12	0.267	1.0	0.517	0.517	1.936
4-Pole, 25-cycle to 40-cycle	2	3.200	1.0	1.789	1.789	0.558
	6	1.070	1.0	1.034	1.034	0.967
	8	0.800	1.0	0.894	0.894	1.115
	10	0.640	1.0	0.800	0.800	1.250
	12	0.530	1.0	0.728	0.728	1.372
6-Pole, 25-cycle to 40-cycle	2	4.800	1.0	2.186	2.186	0.457
	4	2.400	1.0	1.549	1.549	0.645
	8	1.200	1.0	1.099	1.099	0.916
	10	0.960	1.0	0.980	0.980	1.020
	12	0.800	1.0	0.894	0.894	1.115
8-Pole, 25-cycle to 40-cycle	2	6.400	1.0	2.529	2.529	0.398
	4	3.200	1.0	1.789	1.789	0.558
	6	2.120	1.0	1.456	1.456	0.686
	10	1.280	1.0	1.131	1.131	0.884
	12	1.130	1.0	1.063	1.063	0.942
10-Pole, 25-cycle to 40-cycle	2	8.000	1.0	2.828	2.828	0.354
	4	4.000	1.0	2.000	2.000	0.500
	6	2.670	1.0	1.634	1.634	0.613
	8	2.000	1.0	1.414	1.414	0.707
	12	1.330	1.0	1.153	1.153	0.868
12-Pole, 25-cycle to 40-cycle	2	9.600	1.0	3.100	3.100	0.322
	4	4.800	1.0	2.186	2.186	0.457
	6	3.200	1.0	1.789	1.789	0.558
	8	2.400	1.0	1.549	1.549	0.645
	10	1.920	1.0	1.386	1.386	0.722

Table XIX—Multipliers to Use When Changing from 25 to 30 Cycles with the Horsepower Remaining the Same

Change From	Poles	R.P.M.	Hp.	Line Volts	Circ. Mils.	Turns
2-Pole, 25-cycle to 30-cycle	4	0.60	1.0	0.775	0.775	1.291
	6	0.40	1.0	0.632	0.632	1.580
	8	0.30	1.0	0.547	0.547	1.832
	10	0.24	1.0	0.490	0.490	2.041
	12	0.20	1.0	0.447	0.447	2.235
4-Pole, 25-cycle to 30-cycle	2	2.40	1.0	1.549	1.549	0.645
	6	0.80	1.0	0.894	0.894	1.115
	8	0.60	1.0	0.775	0.775	1.291
	10	0.48	1.0	0.693	0.693	1.443
	12	0.40	1.0	0.632	0.632	1.580
6-Pole, 25-cycle to 30-cycle	2	3.60	1.0	1.898	1.898	0.526
	4	1.80	1.0	1.342	1.342	0.746
	8	0.90	1.0	0.948	0.948	1.053
	10	0.72	1.0	0.848	0.848	1.178
	12	0.60	1.0	0.775	0.775	1.291
8-Pole, 25-cycle to 30-cycle	2	4.80	1.0	2.186	2.186	0.457
	4	2.40	1.0	1.549	1.549	0.645
	6	1.60	1.0	1.260	1.260	0.790
	10	0.96	1.0	0.980	0.980	1.020
	12	0.80	1.0	0.894	0.894	1.115
10-Pole, 25-cycle to 30-cycle	2	6.00	1.0	2.450	2.450	0.408
	4	3.00	1.0	1.732	1.732	0.576
	6	2.00	1.0	1.414	1.414	0.707
	8	1.50	1.0	1.220	1.220	0.813
	12	1.00	1.0	1.000	1.000	1.000
12-Pole, 25-cycle to 30-cycle	2	7.20	1.0	2.682	2.682	0.373
	4	3.60	1.0	1.898	1.898	0.526
	6	2.40	1.0	1.549	1.549	0.645
	8	1.80	1.0	1.342	1.342	0 746
	10	1.44	1.0	1.200	1.200	0.833

Table XX—Multipliers to Use When Changing from 30 to 60 Cycles with the Horsepower Remaining the Same

Change From	Poles	R.P.M.	Hp.	Line Volts	Circ. Mils.	Turns
2-Pole, 30-cycle to 60-cycle	4	1.000	1.0	1.000	1.000	1.000
	6	0.667	1.0	0.817	0.817	1.225
	8	0.500	1.0	0.707	0.707	1.414
	10	0.400	1.0	0.632	0.632	1.580
	12	0.330	1.0	0.574	0.574	1.740
4-Pole, 30-cycle to 60-cycle	2	4.00	1.0	2.000	2.000	0.500
	6	1.33	1.0	1.150	1.150	0.864
	8	1.00	1.0	1.000	1.000	1.000
	10	0.80	1.0	0.894	0.894	1.115
	12	0.67	1.0	0.818	0.818	1.220
6-Pole, 30-cycle to 60-cycle	2	6.00	1.0	2.450	2.450	0.408
	4	3.00	1.0	1.732	1.732	0.576
	8	1.50	1.0	1.220	1.220	0.813
	10	1.20	1.0	1.099	1.099	0.916
	12	1.00	1.0	1.000	1.000	1.000
8-Pole, 30-cycle to 60-cycle	2	8.00	1.0	2.828	2.828	0.354
	4	4.00	1.0	2.000	2.000	0.500
	6	2.67	1.0	1.634	1.634	0.613
	10	1.60	1.0	1.260	1.260	0.790
	12	1.30	1.0	1.140	1.140	0.877
10-Pole, 30-cycle to 60-cycle	2	10.00	1.0	3.162	3.162	0.316
	4	5.00	1.0	2.236	2.236	0.446
	6	3.33	1.0	1.825	1.825	0.548
	8	2.50	1.0	1.581	1.581	0.633
	12	2.30	1.0	1.516	1.516	0.659
12-Pole, 30-cycle to 60-cycle	2	12.00	1.0	3.460	3.460	0.288
	4	6.00	1.0	2.450	2.450	0.408
	6	4.00	1.0	2.000	2.000	0.500
	8	3.00	1.0	1.732	1.732	0.576
	10	2.40	1.0	1.549	1.549	0.645

Table XXI—Multipliers to Use When Changing from 30 to 50 Cycles with the Horsepower Remaining the Same

Change From	Poles	R.P.M.	Hp.	Line Volts	Circ. Mils.	Turns
2-Pole, 30-cycle to 50-cycle	4	0.833	1.0	0.912	0.912	1.094
	6	0.555	1.0	0.744	0.744	1.340
	8	0.416	1.0	0.645	0.645	1.550
	10	0.338	1.0	0.581	0.581	1.718
	12	0.278	1.0	0.527	0.527	1.890
4-Pole, 30-cycle to 50-cycle	2	3.380	1.0	1.838	1.838	0.544
	6	1.100	1.9	1.048	1.048	0.952
	8	0.833	1.0	0.912	0,912	1.094
	10	0.667	1.0	0.817	0.817	1.225
	12	0.555	1.0	0.744	0.744	1.340
6-Pole, 30-cycle to 50-cycle	2	5.000	1.0	2.236	2.236	0 446
	4	2.500	1.0	1.581	1.581	0 633
	8	1.250	1.0	1.120	1.120	0.896
	10	1.000	1.0	1.000	1.000	1.000
	12	0.833	1.0	0.912	0.912	1.094
8-Pole, 30-cycle to 50-cycle	2	6.67	1.0	2.582	2.582	0.387
	4	3.38	1.0	1.838	1.838	0.543
	6	2.22	1.0	1.489	1.489	0.670
	10	1.33	1.0	1.150	1.150	0.864
	12	1.11	1.0	1.054	1.054	0.949
10-Pole, 30-cycle to 50-cycle	2	8.33	1.0	2.707	2.707	0.325
	4	4.16	1.0	2.039	2.039	0.490
	6	2.78	1.0	1.667	1.667	0.600
	8	2.08	1.0	1.442	1.442	0.693
	12	1.39	1.0	1.179	1.179	0.848
12-Pole, 30-cycle to 50-cycle	2	10.00	1.0	3.162	3.162	0 316
	4	5.00	1.0	2.236	2.236	0.446
	6	3.33	1.0	1.825	1.825	0.548
	8	2.50	1.0	1.581	1.581	0.633
	10	2.00	1.0	1.414	1.414	0.707

give the multiple for each factor. Table XIV on the 30- to 60-cycle line, indicates that a 30-cycle motor to operate on 60 cycles will have the speed increased 100 per cent and to keep the horsepower the same the 60-cycle line voltage must be 1.414 times the 30-cycle voltage. If the voltage can not be varied then the turns will have to be .707 times the 30-cycle turns and the copper cross section 1.414 times the 30-cycle cross section of copper. Table XV can be used in the same way.

Change No. 4—The next type of change requires that the horsepower be kept constant and that the speed be kept as near as possible to the same value. Tables XVI to XXV give values for this type of change. Consider a 15-hp., 220-volt, three-phase, 25-cycle, 750-r.p.m. motor which it is desired to use on a 60-cycle, 220-volt line, and on an application that only requires 15 hp. On consulting Table XVI in the four-pole, 25-cycle section, we find an eight- or ten-pole winding can be used on 60 cycles. The eight-pole, 60-cycle winding r.p.m. will be 750×1.2 or 900 and the ten-pole will be $.96 \times 750$ or 720 r.p.m. With a ten-pole, (*Continued on page 211*)

Table XXII—Multipliers to Use When Changing from 30 to 40 Cycles with the Horsepower Remaining the Same

Change From	Poles	R.P.M.	Hp.	Line Volts	Circ. Mils.	Turns
2-Pole, 30-cycle to 40-cycle	4	0.667	1.0	0.817	0.817	1.225
	6	0.444	1.0	0.666	0.666	1.500
	8	0.338	1.0	0.581	0.581	1.718
	10	0.267	1.0	0.517	0.517	1.936
	12	0.222	1.0	0.471	0.471	2.121
4-Pole, 30-cycle to 40-cycle	2	2.67	1.0	1.634	1.634	0.613
	6	0.89	1.0	0.943	0.943	1.059
	8	0.667	1.0	0.817	0.817	1.225
	10	0.533	1.0	0.730	0.730	1.369
	12	0.444	1.0	0.666	0.666	1.500
6-Pole, 30-cycle to 40-cycle	2	4.000	1.0	2.000	2.000	0.500
	4	2.000	1.0	1.414	1.414	0.707
	8	1.000	1.0	1.000	1.000	1.000
	10	0.800	1.0	0.894	0.894	1.115
	12	0.667	1.0	0.817	0.817	1.225
8-Pole, 30-cycle to 40-cycle	2	5.33	1.0	2.308	2.308	0.433
	4	2.685	1.0	1.637	1.637	0.609
	6	1.78	1.0	1.334	1.334	0.749
	10	1.06	1.0	1.029	1.029	0.970
	12	0.89	1.0	0.943	0.943	1.059
10-Pole, 30-cycle to 40-cycle	2	6.67	1.0	2.582	2.582	0.387
	4	3.38	1.0	1.838	1.838	0.543
	6	2.22	1.0	1.489	1.489	0.670
	8	1.667	1.0	1.292	1.292	0.776
	12	1.11	1.0	1.054	1.054	0.949
12-Pole, 30-cycle to 40-cycle	2	8.0	1.0	2.282	2.282	0.354
	4	4.00	1.0	2.000	2.000	0.500
	6	2.67	1.0	1.634	1.634	0.613
	8	2.00	1.0	1.414	1.414	0.707
	10	1.60	1.0	1.260	1.260	0.790

Table XXIII — Multipliers to Use When Changing from 40 to 50 Cycles with the Horsepower Remaining the Same

Change From	Poles	R.P.M.	Hp.	Line Volts	Circ. Mils.	Turns
2-Pole, 40-cycle to 50-cycle	4	0.625	1.0	0.789	0.789	1.262
	6	0.416	1.0	0.645	0.645	1.550
	8	0.313	1.0	0.559	0.559	1.786
	10	0.250	1.0	0.500	0.500	2.000
	12	0.208	1.0	0.456	0.456	2.192
4-Pole, 40-cycle to 50-cycle	2	2.500	1.0	1.581	1.581	0.633
	6	0.833	1.0	0.912	0.912	1.094
	8	0.625	1.0	0.789	0.789	1.262
	10	0.500	1.0	0.707	0.707	1.414
	12	0.416	1.0	0.645	0.645	1.550
6-Pole, 40-cycle to 50-cycle	2	3.750	1.0	1.936	1.936	0.516
	4	1.875	1.0	1.369	1.369	0.730
	8	0.938	1.0	0.968	0.968	1.032
	10	0.750	1.0	0.866	0.866	1.115
	12	0.625	1.0	0.789	0.789	1.262
8-Pole, 40-cycle to 50-cycle	2	5.000	1.0	2.236	2.236	0.446
	4	2.500	1.0	1.581	1.581	0.633
	6	1.667	1.0	1.292	1.292	0.776
	10	1.000	1.0	1.000	1.000	1.000
	12	0.833	1.0	0.912	0.912	1.094
10-Pole, 40-cycle to 50-cycle	2	6.250	1.0	2.500	2.500	0.400
	4	3.125	1.0	1.767	1.767	0.568
	6	2.080	1.0	1.442	1.442	0.693
	8	1.560	1.0	1.249	1.249	0.800
	12	1.040	1.0	1.019	1.019	0.979
12-Pole, 40-cycle to 50-cycle	2	7.500	1.0	2.738	2.738	0.365
	4	3.750	1.0	1.936	1.936	0.516
	6	2.500	1.0	1.581	1.581	0.633
	8	1.875	1.0	1.368	1.368	0.729
	10	1.500	1.0	1.220	1.220	0.813

Table XXIV—Multipliers to Use When Changing from 40 to 60 Cycles with the Horsepower Remaining the Same

Change From	Poles	R.P.M.	Hp.	Line Volts	Circ. Mils.	Turns
2-Pole, 40-cycle to 60-cycle	4	0.750	1.0	0.866	0.866	1.115
	6	0.500	1.0	0.707	0.707	1.414
	8	0.375	1.0	0.612	0.612	1.632
	10	0.300	1.0	0.547	0.547	1.832
	12	0.250	1.0	0.500	0.500	2.000
4-Pole, 40-cycle to 60-cycle	2	3.000	1.0	1.732	1.732	0.576
	6	1.000	1.0	1.000	1.000	1.000
	8	0.750	1.0	0.866	0.866	1.115
	10	0.600	1.0	0.775	0.775	1.291
	12	0.500	1.0	0.707	0.707	1.414
6-Pole, 40-cycle to 60-cycle	2	4.500	1.0	2.121	2.121	0.471
	4	2.250	1.0	1.500	1.500	0.667
	8	1.125	1.0	1.060	1.060	0.942
	10	0.900	1.0	.....	.....	.....
	12	0.750	1.0	0.866	0.866	1.115
8-Pole, 40-cycle to 60-cycle	2	6.000	1.0	2.450	2.450	0.408
	4	3.000	1.0	1.732	1.732	0.576
	6	2.000	1.0	1.414	1.414	0.707
	10	1.200	1.0	1.099	1.099	0.916
	12	1.000	1.0	1.000	1.000	1.000
10-Pole, 40-cycle to 60-cycle	2	7.500	1.0	2.738	2.738	0.365
	4	3.750	1.0	1.936	1.936	0.516
	6	2.500	1.0	1.581	1.581	0.633
	8	1.875	1.0	1.369	1.369	0.730
	12	1.250	1.0	1.120	1.120	0.896
12-Pole, 40-cycle to 60-cycle	2	9.000	1.0	3.000	3.000	0.333
	4	4.500	1.0	2.121	2.121	0.471
	6	3.000	1.0	1.732	1.732	0.576
	8	2.250	1.0	1.500	1.500	0.667
	10	1.800	1.0	1.342	1.342	0.746

Table XXV—Multipliers to Use When Changing from 50 to 60 Cycles with the Horsepower Remaining the Same

Change From	Poles	R.P.M.	Hp.	Line Volts	Circ. Mils.	Turns
2-Pole, 50-cycle to 60-cycle	4	0.600	1.0	0.775	0.775	1.291
	6	0.400	1.0	0.632	0.632	1.580
	8	0.300	1.0	0.547	0.547	1.832
	10	0.240	1.0	0.490	0.490	2.041
	12	0.200	1.0	0.447	0.447	2.235
4-Pole, 50-cycle to 60-cycle	2	2.400	1.0	1.549	1.549	0.645
	6	0.800	1.0	0.894	0.894	1.115
	8	0.600	1.0	0.775	0.775	1.291
	10	0.480	1.0	0.693	0.693	1.443
	12	0.400	1.0	0.632	0 632	1.580
6-Pole, 50-cycle to 60-cycle	2	3.600	1.0	1.898	1.898	0.526
	4	1.800	1.0	1.342	1.342	0.746
	8	0.900	1.0	0.948	0.948	1.053
	10	0.720	1.0	0.848	0.848	1.178
	12	0.600	1.0	0.775	0.775	1.291
8-Pole, 50-cycle to 60-cycle	2	4.800	1.0	2.186	2.186	0.457
	4	2.400	1.0	1.549	1.549	0.645
	6	1.600	1.0	1.260	1.260	0.790
	10	0.960	1.0	0.980	0.980	1.020
	12	0.800	1.0	0.894	0.894	1.115
10-Pole, 50-cycle to 60-cycle	2	6.000	1.0	2.450	2.450	0.408
	4	3.000	1.0	1.732	1.732	0.576
	6	2.000	1.0	1.414	1.414	0.707
	8	1.500	1.0	1.220	1.220	0.813
	12	1.000	1.0	1.000	1.000	1.000
12-Pole, 50-cycle to 60-cycle	2	7.200	1.0	2.682	2.682	0.373
	4	3.600	1.0	1.898	1.898	0.526
	6	2.400	1.0	1.549	1.549	0.645
	8	1.800	1.0	1.342	1.342	0.746
	10	1.440	1.0	1.200	1.200	0.833

INDUSTRIAL ENGINEER

Devoted to the Maintenance and Operation of Electrical and Associated Mechanical Systems in Mills and Factories

DANIEL H. BRAYMER
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Assisted by

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Chicago, April, 1924

What Do Increased Speeds Give Us?

SPEEDS, like styles, change periodically, sometimes for the better and sometimes for the worse. It seems that the popular trend is toward more rapidly-moving machinery. The advocates of higher speeds hold out the attractions of increased production and lower first cost. On the other hand, claims are made that the resulting lower maintenance and reduced production delays from the lower-speed machinery overbalance the advantages of increased speed.

In deciding whether increased speeds are justified in a particular application, it is well to balance the relative advantages as applied to the case in question. This brings to mind the case of a billet mill with very high roll-table speeds. The purpose of this was to obtain a very fast mill. After the mill had been put in operation it was found that the table speeds were so high that there was excessive slippage of the steel billets on the rolls. This meant that the steel did not travel as fast as was intended; in fact, when the roll speed was reduced, the billet speed was increased.

There is also recalled the case of a coal bridge with a 200-ft. span and a trolley speed of 500 ft. per min. This high trolley speed could never be utilized because the average travel of the trolley was approximately 100 ft. and the trolley did not have time to accelerate to this speed. Increasing the gear ratio between the motor and the track wheels brought about a lower running speed, but actually decreased the traveling time of the trolley and greatly increased the number of trips made during a given time. This was due to the faster acceleration obtained through increasing the gear ratio.

Still another case may be mentioned—that of a skull cracker crane with a runway length of 100 ft. and a bridge motion speed of 200 ft. per min. Most of the movements made by the crane averaged about 10 ft. of travel. Obviously the high bridge speed was of no value; in fact, the bridge runway was not long enough to get the bridge up to full speed without danger of not being able to stop quickly enough to avoid running into the bumper at the other end of the runway.

Such examples as these illustrate the necessity of a very careful analysis of each case in which higher speeds are being considered, so that a careful balance may be drawn between the factors of production, first cost, maintenance and production delays. In many cases increased speeds will actually show economies and increased earnings, but indiscriminate use of them, just as a great many people follow the styles in clothing and hair bobbing, are not likely to produce the records operating men like to talk about.

Everybody's Business Is Nobody's Business

SO COMPLEX and varied are the every-day jobs of industrial men, that some sort of organization for accident prevention is imperative. The very large plants with many departments spread over wide areas have met this issue by establishing safety engineering organizations. Other establishments are getting good results through special committees whose members supervise or conduct regular inspections and prepare reports of findings for discussion by themselves and their executives.

Now a movement is getting under way to turn the thinking of maintenance men into safety engineering channels. This idea is just as practical as it is brilliant. Such men have "the run of the plant," which removes their activities from the tender zones of interdepartmental authority. Since inspection forms such an important part of maintenance work in general, it would seem that the keen eyes and alert brains of the plant engineer's staff from the "big boss" down might well be more generally utilized in this very essential field of service. Of all this, more anon, but in the meantime let us be thinking about the fitness of maintenance personnel to undertake broader activities, co-operating with safety departments and committees where such are functioning, and pointing the way toward more thorough and systematic inspection in industrial plant operation as a whole.

Over-Motoring and Under-Motoring

SINCE manufacturers through the Electric Power Club standardized on one rating for general purpose motors, much of the confusion resulting from two standards of motor ratings has been eliminated and there should be no further cause for over-motoring or under-motoring. Over-motoring is poor practice from the industrial engineer's standpoint because it results in putting unnecessary expenditure in plant capitalization. Also, in the case of induction motors, it results in poor power factor requiring either a larger generating and distribution system or else power factor corrective apparatus, which necessitates a still larger increase in plant capitalization. Under-motoring is still worse because it runs up operating costs through increased maintenance and repairs and cuts down income through decreased production resulting from repairs and delays.

The factors governing motor applications and the traditions concerning what is required for a given installation have grown up around the 40-deg. motor. The industrial engineer in using any other rating governs himself to a large extent by his experience

with the 40-deg. motor and consequently many applications of 50-deg. motors have resulted in under-motoring an installation.

The adoption of the single standard of motor rating represents an economic saving not only to the manufacturers in standardization of designs and construction details, but also to the large number of motor users in the savings that will result from reduced plant investment and decreased maintenance due to correct motor applications.

How, Where and Why?

HERE'S a common-sense viewpoint that is worthy of some study. It is taken from the introduction of a sales bulletin, of an electrical instrument manufacturer, that says little about the instruments but much about the ways they can be used in industrial work to locate weak spots, to detect avoidable losses and to prevent troubles. Its obvious purpose is to sell instruments, but the way it goes about it reflects a knowledge of the operator's problems and carries the conviction that when the operator realizes what he can accomplish with them, his good judgment will either dictate the purchase or open negotiations leading thereto without a flowery dissertation on the excellence of design and the usual sales verbiage that carries little practical information but much display of expensive and complicated illustrations and general talk.

As a nation we are reputed to be the keenest manufacturers on the globe and certain it is that when we buy raw materials or anything else entering into the cost of our products. we display unusual caution and intelligence. If this be so, why is it that the same degree of supervision as to cost and efficiency has not been generally applied to the purchase and use of electrical energy and electrical equipment?

The only conceivable answer is that the opportunities for saving have not been understood or else the subject has not been carefully studied; for it is obvious that electrical power costs money to generate and distribute and that like any other commodity it is susceptible to waste if not properly utilized. Furthermore, our knowledge of factory equipment in general convinces us that mechanical or electrical equipment must be kept in the most ideal condition if we desire to prolong its life and make it do the maximum amount of useful work.

The preceding remarks have a direct bearing upon the question of profits, for it is well known that there are two ways of increasing profits: one being to increase selling prices without additional manufacturing costs; the other, and more satisfactory method, being that of reducing manufacturing costs while maintaining usual selling prices, thus avoiding encouragement of competition. And it is with this latter method that the following pages deal.

Lest you say to yourself that our remarks are merely a cloak to conceal the fact that we eventually hope to sell you some testing instruments, we at once proceed to remove any doubt on that score by acknowledging that our case is exactly like your own in that we are in business to sell the products which we manufacture. However, we wish to emphasize this significant fact: namely, that we do not want to sell without rendering service and for every sale we make of the apparatus referred to in this book, our profits shall be reasonable and made only once, whereas your profit derived through its use by saving energy and protecting your electrical equipment, should annually be more than tenfold ours and should continue indefinitely.

Most pieces of literature produced by a manufacturer dealing with the products he makes and sells are interesting reflections of the way readers do not use that literature. The general impression that the usual catalog gives is that the user and buyer of the apparatus needs an equipment dictionary which he can consult, with competitive sales information on how good the material or equipment is and information to prove that everybody is using it. *How, where* and *why* the product is used are points left to the imagination. And yet answers to questions on how, where and why are the points around which discussions revolve when talking with a prospective buyer on his home ground, where the practical problems of a job to be done that needs this or that piece of apparatus forces answers to these questions.

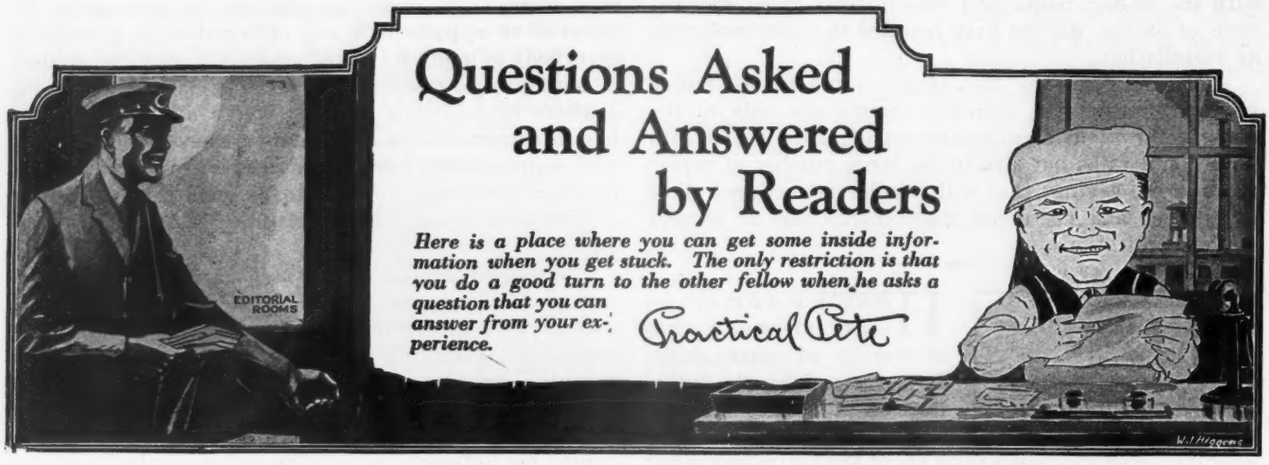
Moreover, a good answer to the *why* will often suggest an answer to the *how* and *where* in the mind of the user because he has the everyday problem of improving operations, installing new ones, avoiding troubles and reducing existing costs. He usually knows *where* to direct his attention but on *how* and *why* he should use something new or different, there is a wide opportunity for difference of opinion and a whole lot of conversation. Out of this the manufacturer wins or loses a customer. If he has a good argument on his side in answer to the *why* of the problem and it will save money or improve operation the chances for a sale are good. But when the silent salesman in the form of a bulletin says nothing or little about the *how, where* and *why*, it's just a piece of printed matter for which most of us have little more than a flying glance.

When Temporary Installations Become Permanent

ORDINARILY it is good policy to obey orders, or be able to show very good reasons for not doing so. However, when such orders conflict with the teachings of experience, the man to whom the instructions have been given is confronted with a situation which requires much tact and good judgment for its solution. The manner in which the foreman in charge of the installation and maintenance of lineshafts and other power service equipment handles such situations was recently told by the electrical engineer of a large works.

"Often during our rush season it is necessary to rearrange machines or put up new lineshafts and countershafts. Frequently these are intended to be only temporary installations and it is very important to get them into operation as soon as possible—for every hour may mean a heavy loss in production—but I can't get John to do anything except a first-class job. I have given him the strictest orders to hurry things through, and I have threatened him with all sorts of penalties, but it doesn't do any good. He doesn't argue about it, but I can't force him to turn over the job until everything is properly lined up and in good shape. For him, temporary installations simply do not exist—and he is absolutely right!"

So-called temporary installations have their place, of course, but unless they have been put in to meet an emergency and are removed or revamped after they have served that particular purpose they assume the status of permanent, poorly-aligned, power-wasting installations of lineshafts, chains, gears and all of the other elements of power drives. The few dollars that may be saved by doing a hurried, slipshod job of installation are soon wasted by the friction and other losses —and then these losses must be paid out of the profits of the business.


EDITORIAL ROOMS
Questions Asked and Answered by Readers
Here is a place where you can get some inside information when you get stuck. The only restriction is that you do a good turn to the other fellow when he asks a question that you can answer from your experience.
Practical Pete

Who Can Answer These?

Removing Flange Couplings from Lineshafting—In the rearrangement of a group of machines, it was necessary to remove some solid pulleys from a lineshaft and replace them with others. This necessitated removing and replacing the flange couplings. We were not able to replace them so that they would run true and had to turn them down. I would like to know how other readers remove and replace flange couplings on lineshafts.

North Chicago, Ill. G. F. H.

* * * *

Meaning of Motor Nameplate Data—Can some reader tell me what "Open Hp. 10, Amps. 75,—Closed Hp. 5½, Amps. 43," means in the case of a General Electric, d. c., compound-wound motor which has the following nameplate data: No. 95790, Form B, Speed 650, Volts 115, Open Hp. 10, Amps. 75—Closed Hp. 5½, Amps. 43. Pat'd Feb. 14-88 up to Jan. 31-99.

Mazatlan, Sinaloa, Mex. J. C. L.

* * * *

Supporting Load from Concrete Ceiling—In the rearrangement of the plant with which I am connected, we frequently find it necessary to suspend conveyors, motor platforms, countershafts, heavy radiators, and similar equipment from the ceiling of a reinforced concrete building. I am wondering if any of the readers of INDUSTRIAL ENGINEER have any information on how heavy a load can be supported from expanded bolts. I would also like to find out what other readers consider the best method of fastening equipment to the ceiling.

Chicago, Ill. E. D. F.

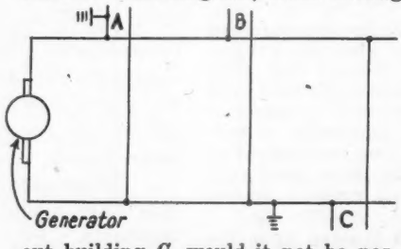
* * * *

Does Voltage Above Normal Affect Power Bill?—We buy power from a local power company at a line voltage of 13,000 volts. The voltage in the plant is supposed to be 550, but we have an average voltage of 640 to 700. Our motors are of the induction type, ranging from 1/10 to 50 hp. Will there be any loss of power with the voltage higher than normal? If so, what will it amount to? When the voltage jumps from 620 to 700 our indicating wattmeter will rise around 200 watts. Will this increase the reading of our kw.-hr. meter in proportion, or what per cent will it be? I have been checking very closely the power consumed and find that when we have high voltage the power runs higher also. I shall be very grateful for any information you can give me.

Rock Hill, S. C. L. W. M.

* * * *

Why Do Grounds Not Blow Fuses in Power House?—It always takes two grounds of opposite polarity to make a short circuit. In cities or in large industrial plants where there is much conduit work, there must be grounds. If there is a ground on the negative side of one building and a ground on the positive side of another, why would these not blow the main fuse or open the breaker in the power house? Again, under the conditions shown in the diagram, when testing



out building *C*, would it not be possible to obtain results which would make one think that there is a ground somewhere in this building whereas it is located in building *A* or *B*?

Worcester, Mass. F. R. B.

* * * *

Trouble with Single-Phase Induction Motor—Can some of the readers of INDUSTRIAL ENGINEER tell me what is the matter with a small, single-phase induction motor which fails to start when the switch is closed? Both the main and starting windings and the centrifugal switch have been tested and seem to be all right. After closing the line switch and giving the rotor a quick start by means of a string, the rotor will sometimes quickly come to a stop, or apparently lock. Then, possibly the next time the switch is closed the motor will start from rest and run normally. This is a standard make of four-pole, 60-cycle, 110-volt motor. I shall certainly appreciate any suggestions you can give me as to what is the trouble and how it can be remedied.

Uhrichsville, Ohio. R. F. P.

Answers Received To Questions Asked

Portable Electric Grinder Lacks Power—I shall appreciate it if some of our readers will answer the following questions. I have a single-phase portable grinder which has two windings, starting and running, but the motor does not seem to have sufficient power when grinding. I should like to know if this motor could be re-connected for three-phase operation, eliminating the automatic cutout on the rotor. The motor has twenty-four slots ⅝ in. deep and 5/16 in. wide. The iron back of the slots is ⅜ in. thick. Inside diameter of stator is 3⅛ in., length of stator 2½ in., diameter of rotor 3 1/16 in. If this change is possible, what size wire and how many turns should be used and what will the pitch be? I should like to have it operate at 3,600 r.p.m.

I have a small blower motor which operates at 220 volts direct current, and wish to change it to operate at 110 volts direct current. Will I have to reconnect the armature or should it be entirely rewound? The commutator has twenty-four bars and the armature has twelve slots.

Medina, Ohio. C. F. N.

Answering C. F. N.'s question in the February issue, a single-phase motor when rewound for three-phase operation at the same voltage, speed and frequency will develop about 1½ times the original, single-phase hp. rating. Therefore, the motor in question would develop more torque and horsepower on three-phase. Another advantage of the three-phase over the single-phase motor is the elimination of the cutout switch in the starting circuit. Considerable trouble is experienced with these switches sticking and not opening the circuit; this burns out the starting winding and very often the running winding is also ruined. It is a well-known fact that a polyphase motor is more efficient and gives less trouble than a single-phase motor.

The motor in question will be good for ¾ hp. at 3,600 r.p.m. when

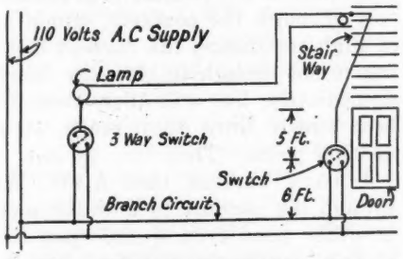
wound for two poles and operated on a three-phase, 60-cycle, 110-volt circuit. There will be twenty-four two-layer mush coils, each coil having sixteen turns of one No. 17 single-cotton and enamel-covered magnet wire, pitch 1 and 8, connected series-star, four coils per group with six groups. For 220 volts, use thirty-two turns of one No. 20 silk-covered and enameled wire, 1 and 8 pitch, with the coils connected series-star.

If possible to do so, I would use a No. 16 wire; this will increase the overload capacity. If high torque is required, use fourteen turns of No. 16 single-cotton and enameled wire with the coils connected series-star for 110 volts. The rotor is OK and will stand 3,600 r.p.m., but be sure that it is well balanced mechanically.

Detroit, Michigan. A. C. ROE.

* * * *

Protecting Wires from Mechanical Injury—How should the 5-ft. stretch of wire from floor to switch, shown in the accompanying diagram, be run for proper protection from mechanical injury? Knob and tube work is used throughout on this job, and the wire in question is to be installed in an unfinished stairway leading to a



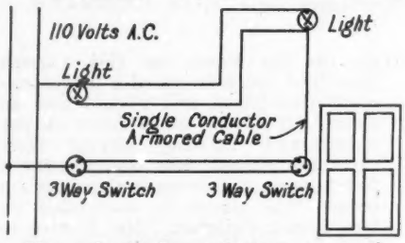
cellar. There is no partition through which to fish the wire. Further, when the wall of the stairway is finished it is to be back-plastered; so there will be no partition even then. I shall appreciate it if some reader can tell me the best way to meet the above conditions.

Concord, Mass. D. F.

In reply to D. F.'s inquiry in the February issue of INDUSTRIAL ENGINEER, the accompanying sketch shows a different method of wiring to accomplish the desired results.

In this arrangement only two soldered and taped joints are required to the feed lines, instead of four. Further, in case of an accidental short across the contacts of either three-way switch no fuse will blow or short circuit in the supply line.

The single wire connection from the three-way switch at the door to the light may be a No. 14 single-conductor, armored flexible cable, which is about 5/16-in. in diameter. If this is too large or for some other reason objectionable, a No. 14 rubber-covered wire may be pulled through a small, annealed copper or brass tube. If this is not feasible a single-conductor, braided copper insulated wire with flexible sheathing, as used in automobile wiring, can be used.



Use of single-conductor armored cable in place where wire is exposed to mechanical injury.

This is about 3/16-in. in diameter and is designed for carrying a low amperage current. E. H. LAABS.

Engineering Dept.,
The Cutler-Hammer Mfg. Co.,
Milwaukee, Wis.

* * * *

Determining Charging Rate for Storage Battery—Can any of the readers of INDUSTRIAL ENGINEER tell me how to find out from a storage battery at what amperage it should be charged?

Temiskaming, Que., Can. J. H. F.

In answer to J. H. F.'s question in the December issue, the approximate charging rate of a storage battery may be determined by multiplying the square inch area of both sides of all the positive plates per cell by 0.04. For example, a power battery has seventeen plates per cell, each plate measuring 18 in. x 20 in. There will be eight positive plates: then $8 \times 2 \times 18 \times 20 \times 0.04 = 230.4$ or 230 amp. charging rate.

If the ampere-hour capacity of the battery is known, the rate may be determined by dividing this by 8. For example, with a battery rated at 1,000 amp.-hrs., $1{,}000 \div 8 = 125$ amp. charging rate.

General Electric Co., L. B. MORRILL.
Boston, Mass.

* * * *

J. H. F., whose question appeared in the December issue, should determine, first, whether the battery needs charging. This is done by placing a voltmeter across the terminals of one cell only. For a lead cell at full charge the voltmeter will read about 2.2 volts; an Edison cell at full charge will read about 1.5 volts. If the voltage of one lead cell reads about 1.8 volts it shows that a recharge is needed; a run-down Edison cell will read about 1.2 volts. In the case of the lead cells apply a direct current of a few amperes, say 8-15 amp. for a trial, to raise the reading of the voltmeter about one or two points. The high limit per cell must not exceed 2.3 volts and this limit should not be reached in a hurry. It should take 6-8 hr. if the battery is much run down. On the other hand, if the voltage does not rise noticeably after about 15 min. increase the charge in amperes, being careful not to heat the cells above 115 deg. F., and do not let the voltage per cell at any time get above 2.6 volts, which is the high limit while on charge.

With the Edison cells make the charge in amperes strong enough to raise the voltage of the meter slowly, taking 6-8 hr. for it to reach the upper limit of about 1.9 volts per cell, and not letting the temperature of the cells exceed 115 deg. F.

For an extended charge, more than 6-8 hr., with the solution temperature not above 115 deg. F., simply reduce the ampere charge enough to keep the voltmeter perhaps one point under the high limit and allow the latter to be reached very gradually. In short, do not exceed the temperature limit or the high voltage limit of any kind of a cell on charge, and the battery will not be injured, even if left on the line at a reduced charge for 12, 15, or 20 hr. H. S. RICH.

New Britain, Conn.

* * * *

The question by J. H. F. in the December issue could without doubt be answered best by the manufacturer from whom the battery was purchased. The charging rate depends upon the active battery surface in a cell and is likely to vary somewhat with different types.

In general for a lead-acid battery any charging rate is permissible that does not produce excessive gassing or a cell temperature greater than 110 deg. F. The value of the charging current at which gassing begins depends principally upon the state of charge of the battery. When a battery is fully discharged, a greater charging rate can be applied without causing gassing than if the battery is almost fully charged. For this reason the common practice is to start charging at a comparatively high rate at the beginning of charge, gradually reducing the rate as the charge progresses. By this method an average battery can be charged in about five hours.

By watching carefully the charging current, specific gravity, and temperature, a suitable charging rate can be determined, always bear-

ing in mind that it is necessary to keep temperature below 110 deg. F. and as soon as gassing is evident, to cut down on the charging rate.

Comerio Falls, Bayamon, Porto Rico. FREDERICK KRUG.

* * * *

Answering the question by J.H.F. in the December issue, the charging rate of a storage battery may be calculated from the area of both sides of the positive plate, allowing 0.04 amp. per sq. in. That is, if the plate surface is 2,500 sq. in., then $0.04 \times 2{,}500 = 100$ amp., charging rate. JOHN H. GRIFFIN.

Cedar Rapids, Ia.

* * * *

Replying to J. H. F., whose question appeared in the December issue, when the charging rate of a storage battery is not given, and in the absence of instructions from the manufacturer of the battery, the charging rate may be determined approximately by calculation, taking .040 amp. per sq. in. of positive plate surface as normal. This may be verified after a few trials by noting the length of time elapsing from the beginning to the end of the charge, as evidenced by the voltage rising to 2.5 and vigorous gassing of the cell. The maximum charging rate is that at which the cell will absorb energy without heating more than 25 deg. F. above a reference temperature of 77 deg. F., or gassing excessively.

Denver, Colo. MARTIN G. LANE.

* * * *

Effect of Armature Coil with Reversed Polarity—Sometime ago this question was raised in our shop: Will a reversed polarity coil in an armature burn out while running, or what effect will it have on the armature?

I contend that in order to burn out a coil a heavy current must flow in that coil, which could only be caused by a short circuit. As all coils are connected in series, current of the same amount would flow in each; if one were reversed it would oppose the action of the others and having only the same amperage through it as the others it could only oppose with the strength of one coil, and would neutralize one armature coil.

I should like to hear from some of the readers of INDUSTRIAL ENGINEER on this question.

McKeesport, Pa. E. K.

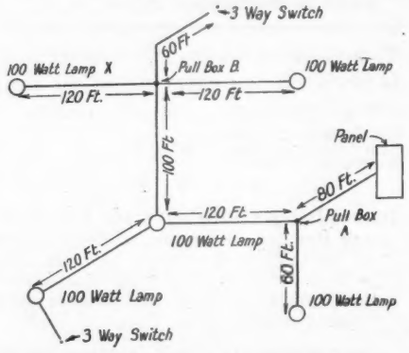
Replying to E. K.'s question in the February issue, I have never seen a reversed armature coil burn out. At the moment of commutation the coil will be under poles of the wrong polarity, causing a reverse emf. which opposes that of the other coils and causes excessive sparking at the brushes, and also lowers the efficiency of the machine.

The winding will heat up to some extent because the circuit containing the reversed coil will generate a lower voltage than the others, thereby causing a circulating current to flow through the winding.

Middleport, Ohio. ELZA HERRMANN.

* * * *

Why Do the Fuses on this Circuit Blow?—I recently wired a large concrete warehouse and should like to know why the 10-amp. fuses on the watchman's lighting circuit blow after the current has been on for a few hours. As shown in the diagram below, this circuit is controlled by two 3-way switches. No. 8 wire in 1-in. conduit is used throughout for this 110-volt a. c. circuit which contains five 100-watt lamps. From the panel to the first pull box, *A*, a circuit of No. 12 wire runs in the same conduit, and from the pull box, *B*, through the light *X*, another circuit of No. 12 wire is pulled through the same conduit. A grounded neutral at the transformer secondary supplies this building. Can some reader help me out?



Los Angeles, Calif. A. W. W.

In answer to A. W. W.'s question in the January issue, I am of the opinion that he has a high-resistance ground on his circuit; perhaps this was caused by a small piece of insulation being nicked off a conductor at an outlet, while pulling in the wires. The length of time required for the fuses to reach their melting temperature may be due to the fact that only a small area of bare copper would be exposed, and that the enamel coating on the inside of the conduit has a high resistance. Again, the trouble may be caused by a pigtail splice, which is generally made at outlet boxes. A sliver of metal at the splice may have pierced the insulation and made contact with the box.

As the transformers are grounded at the secondary neutral I advise temporarily removing the ground wire from the conduit system. If the fuses fail to blow within a reasonable length of time it is evident that the circuit is grounded, even though the ground may be of high resistance. Then replace the ground wire and test for grounds in the usual way.

I hope the above information may assist A. W. W. in locating the trouble on his circuit.

New Orleans, La. OVIDE C. HARRIS.

* * * *

In reply to the question asked by A. W. W. in the January issue, I would suggest that he look for a loose connection close to the fuses, or a loose fuse receptacle or clips. I once had the same trouble on a house installation and after some time I found a loose plug receptacle.

Of course, a partial ground would also cause the fuses to blow; so I advise that he also test out the circuit for a slight ground.

I hope this information will be of some use to A. W. W.

Haledon, N. J. GEORGE ZEHNACKER.

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With reference to A. W. W.'s question in the January issue, from past experience I would say that he has one wire grounded in his conduit fittings at one or more places. Inasmuch as the conduit is grounded only through the concrete, which is of high resistance, the current flowing is not enough to blow the fuses immediately, but will allow them to heat slowly until they reach their melting point. Then they go out.

I would suggest that A. W. W. ground his conduit to a water pipe or other good ground and open the circuit at any convenient place. Be sure to keep the ends of the wires from touching anything. Then throw in the switch at the panel and if the fuses blow immediately it shows that the trouble lies between the place opened and the panel box. If this test shows that the circuit is clear up to this point, keep on opening and testing in this manner until the trouble is located.

Chief Electrician, Booth-Kelly Co., Springfield, Ore. EARLE N. DILLARD.

* * * *

A. W. W. asks in the January issue why the fuses in one of his installations blow. He says in his description that the neutral in the transformer is grounded; so if there is not load enough on the circuit to blow the fuse, there must be a ground at times on the live side.

In a case of trouble which I saw recently a 100-watt lamp in an enclosed shade so heated the wires, which were rubber covered No. 18 fixture wires, that the rubber be-

came softened and through pressure either grounded or short circuited and blew the fuse. A smaller light caused no trouble. The circuit was less than normally loaded with the 100-watt lamp. Something of this sort may also be the cause of A. W. W.'s trouble. EDWARD A. GIBBS.

Boston, Mass.

* * * *

Preventing Corrosion of Iron Storage Battery Racks—I should like to ask your readers what treatment can be given to iron racks for storage batteries which will prevent the spilled acid from attacking the iron. We use the lead type of battery filled with dilute sulphuric acid. We have a large number of storage batteries and recently some iron racks have been constructed. All of these racks were painted with several coats of the best grade of asphaltum black paint but this does not protect the iron when acid is spilled on it, nor does any kind of paint that I have tried.

We have had considerable trouble due to the corrosive effect of the acid forming a substance resembling sand which falls into the jars below. This produces excessive iron in the solution, making a change of acid necessary. I shall appreciate it if anyone can tell me how to overcome this.
Atlanta, Ga. J. B.

In answer to J. B.'s question in a recent issue of INDUSTRIAL ENGINEER, I have had good success in preventing corrosion of battery racks by washing them with strong solution of common baking soda and painting them, when dry, with a mixture of white lead and tallow. This procedure should be repeated as soon as corrosion begins to show again. EARLE N. DILLARD.

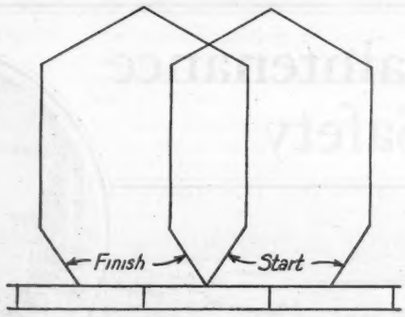
Chief Electrician,
Booth-Kelley Co.,
Springfield, Ore.

* * * *

Commutator Connections of Two-Pole, Compound-Wound Motor — I should like to see a diagram showing how to connect the starting and finishing ends of coils to the commutator of a two-pole, compound-wound motor, which is rated at ¾ hp., 220 volts, 3.7 amp., 1575 r.p.m. The coils have twenty turns of No. 22 s.c.c. wire. There are twenty-four slots, two coils per slot, and forty-eight bars.
Morrero, La. P. D. H.

P. D. H. asks in a recent issue how to connect the commutator leads of a two-pole compound motor. As a general rule, if the coils wind to the left the top leads throw to the left and the bottom leads to the left of the top leads. If the coils wind to the right, the leads throw to the right. If the coils connect to the left the finish lead of one coil connects to the start lead of the next coil to the left.

A compound-wound field does not



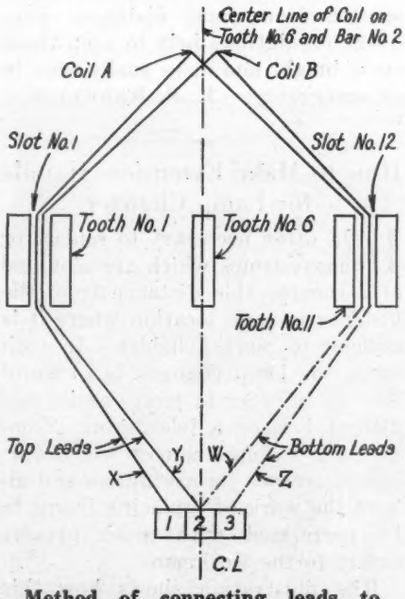
Commutator connections of two-pole, compound-wound motor.

affect the connections on the armature. P. D. H. speaks of using single-cotton-covered wire on the armature. It would be better to use either single-cotton-enameled wire or double-covered cotton, as single-covered cotton shorts easily.

Peoria, Ill. GEORGE RINGNESS,

* * * *

Referring to P. D. H.'s question in a recent issue, the diagram shows the method of connecting the coil leads to the commutator. The coil pitch is 1 and 12. To connect up the armature take any one coil and find its two top leads, as *X* and *Y;* then with a test light find the two bottom leads. Let *W* be the bottom lead of coil *A*, and *Z* that of coil *B*. Next, call the tooth to the right of slot 1, tooth No. 1. Count over to tooth No. 6, as shown, then take a piece of string and find the approximate center of tooth No. 6 and use this string to line out to the commutator on a line parallel to the axis of the shaft. Call the commutator bar this line falls on, No. 2; the bar



Method of connecting leads to commutator of two-pole, compound-wound motor.

to the left of this, No. 1, and the bar to the right of the line out, No. 3. Then put the bottom lead of coil *A* in bar No. 2 and the bottom lead of coil *B* in bar No. 3, as shown by the dotted line. Note that it is immaterial which coils are called *A* and *B*, as these are only indicated in the diagram to illustrate the method of locating the bottom leads. After these two bottom leads are in place, take the bottom leads from the next slot to the right and put one of these in each of the next two adjacent bars. Proceed in this way until all of the bottom leads are down. Then with a test light find the top leads as follows:

With one test lead on bar No. 2, find the top lead that lights and put this top lead in bar No. 1. Then put the test lead on bar No. 3 and find its top lead and put it in bar No. 2. Put the test lead on bar No. 4, find its top lead and put it in bar No. 3, and so on around the armature, working around in a clockwise direction for a left-hand winding. A winding is left-hand when the top or finishing leads are on the left-hand side, looking at the commutator end. For a right-hand winding, proceed in a counter-clockwise direction around the armature.

Detroit, Mich. A. C. ROE,

* * * *

Path Followed by Current in D. C. Generator—I wish some readers would show by a diagram the commutator connections and the path followed by the current in a direct-current generator which has two poles, 29 segments, 15 slots and 15 coils with a winding pitch of 1 and 4. The machine has two brushes set at 90 deg. I removed a short circuit from the armature of this machine and afterwards drew a diagram to trace the current. Owing to the winding pitch I failed to get the right direction of current flow for each coil. I have had considerable experience in winding d. c. and a. c. machines but this is the first time that I have seen a machine of this design.
Libby, Mont. J. Q. W.

In a recent issue of INDUSTRIAL ENGINEER, J. Q. W. asked for the connection diagram of a two-pole d.c. generator which has twenty-nine segments, fifteen coils and fifteen slots. From the description of this armature I believe that if he will examine the fields he will find that the machine has two field coils and four pole pieces, two of the pole pieces having no winding on them, but receiving their flux from the other two which are connected for the same polarity. A. SOULEN.

Warren, Ind.

Building Maintenance and Plant Safety

The object of this department is to give details of building maintenance procedure and best practice in safety work. Articles on ways of handling natural wear and tear or other depreciation, repair methods, rebuilding, extensions, cleaning and painting operations will always be welcome.

Red Spot on Wall Behind Fire Extinguisher Saves Priceless Seconds

AS A result of familiarity through constant occupation of a shop the equipment for fire protection tends to become commonplace and out of mind, unless attention is focused upon it. One way of doing this is by means of bright signs. In a Connecticut factory the panels on the wall behind the extinguishers are painted bright red (red photographs black) as indicated in the accompanying illustration. In addition, the fire prevention rules, which tell what to do in case of fire, are mounted above the extinguisher. The eye inevitably "takes in" the extinguisher as it hangs in front of such a background as it is only necessary to look for the "red spot."

A red panel on the wall points out the fire extinguisher.

After workers have grown familiar with their surroundings through constant association their eyes may pass over a fire extinguisher in an emergency, unless it is made to stand out from its surroundings. The red background, if kept bright by frequent paintings, makes it easy to "spot" fire protection equipment even from some distance.

In the shop yard red arrows with signs indicate the location of the factory fire alarm boxes. These are also found helpful in locating this protective installation in a hurry. The red panels and arrows should be large enough so that they can be spotted from some distance. Frequent repaintings help to keep these spots bright and more easily seen in an emergency. H. S. KNOWLTON.

Boston, Mass.

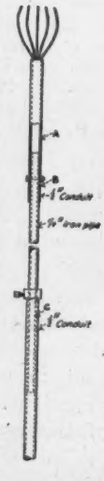
How to Make Extension Handle for Lamp Changer

IT IS often necessary to replace or remove lamps which are mounted at a considerable distance from the floor, or in some location where it is difficult to place a ladder. In such cases the lamp changer is a useful device. In order to meet special conditions I made a telescoping extension for a lamp changer which further increases its usefulness and allows the work of replacing lamps to be performed with much greater safety to the workman.

The illustration shows how this extension was made. The lamp changer was forced onto a short length of ½-in. conduit, *A*. A 10-in. length of ¼-in. pipe was then attached to the piece of conduit by a rivet, *B*, which passes through both pipe and conduit. Then a piece of ½-in. conduit 10 ft. long, *C*, was slipped over the ¼-in. pipe. A coupling was sawed through on one side, parallel to its axis, and slipped over the upper end of the conduit. This coupling, as well as the conduit, was drilled and tapped for a ¼-in. setscrew, the coupling being used to give a greater thickness of metal to hold the setscrew.

When using the lamp changer the handle is extended to the proper length and the setscrew tightened; after using it the setscrew is loosened and the handle telescoped so that it can be carried more easily or stowed away conveniently until needed again. J. H. SAUVE.

Temiskaming Que., Can.



The lamp changer is mounted on a 10-ft. length of iron pipe which fits into another 10-ft. length of conduit and is held in place by a setscrew.

Practical Safety Don'ts for the Electrical Department

THE following list of safety dont's is multigraphed on an 8-in. by 11-in. sheet and furnished to the members of our electrical department. Before beginning work each new man is required to read and sign a copy.

REGULATIONS FOR THE ELECTRICAL DEPARTMENT

DON'T—Start motor before ringing signal bell, and waiting 15 seconds.

DON'T—Start a motor having a caution sign on controller before inspecting shafting or machine that motor drives.

DON'T—Use ladders without spurs.

DON'T—Use ladders with broken or dull spurs.

DON'T—Use broken ladders or any but regulation type.

DON'T—Use short ladders on boxes or blocks.

DON'T—Use ladders as supports for scaffolds or heavy weights.

DON'T—Work above machines in motion.

DON'T—Work on ladders in traffic aisles, alleys or runways without man on floor end.

DON'T—Work on poles, long ladders, high scaffolds or in boatswains chair if unfamiliar.

DON'T—Use metallic rules, tapes or metal-bound wood rules around live apparatus.

DON'T—Work near rope or belt drives in motion with any loose wire, hauling ropes, or loose-fitting clothes.

DON'T—Take any wiring or construction materials from storeroom without written order by Shop Attendant. Give him job number when ordering.

DON'T—Leave any supplies or waste material on job after completion. Return them to storeroom and give list to Shop Attendant to credit job with. This applies to both old and new material.

DON'T—Use solder melting or cable-splicing apparatus without having two fire extinguishers near at hand.

DON'T—Use any matches that are not of approved safety type provided by the company.

DON'T—Leave material of any description lying around job, on floors, boxes or shelves. Keep together in suitable receptacle. **Violation of this rule is cause for dismissal.**

DON'T—Lay tools or loose material on scaffolds, beams, overhead platforms or any place where liable to fall.

While these safety rules and regulations apply particularly to conditions in our textile mill they will no doubt also apply as well to the work of men engaged in the installation and maintenance of mechanical equipment for any mill or factory.

WILLIAM MCNALLY.

American Manufacturing Co.,
Brooklyn, N. Y.

Painting with Air Brush at One-Fifth of Brush Work Cost

RECENTLY a midwestern factory in enlarging its quarters found it necessary to repaint the interior of a building which had not been painted for several years. As time was an important element a portable paint spray outfit was purchased and one man put at work. The cost of air painting on this job was about one-fifth of the lowest estimate on what it would have cost by hand. The total saving amounted to several thousand dollars. In addition the compressed air forced the paint into all cracks and closed them up securely and permanently.

Removing Large Foundations With Dynamite

REMOVING concrete foundations by ordinary methods is a slow and expensive job. As in most cases this is rush work, other methods, such as the use of dynamite, sometimes offer opportunities to speed up the work and decrease the cost. For example, dynamite was successfully employed recently at a Philadelphia paint works to blast out a concrete pit which carried a set of track scales and was removed to make way for larger scales. The pit was about 65 ft. in length and its four walls were approximately 2 ft. in thickness and 10 ft. deep. It was also tied in at the bottom with heavy concrete cross sections.

The job presented some difficulties, because one of the side walls of the pit was about 2 ft. from a building with a number of windows. A similar building was located across the roadway some 20 ft. distant.

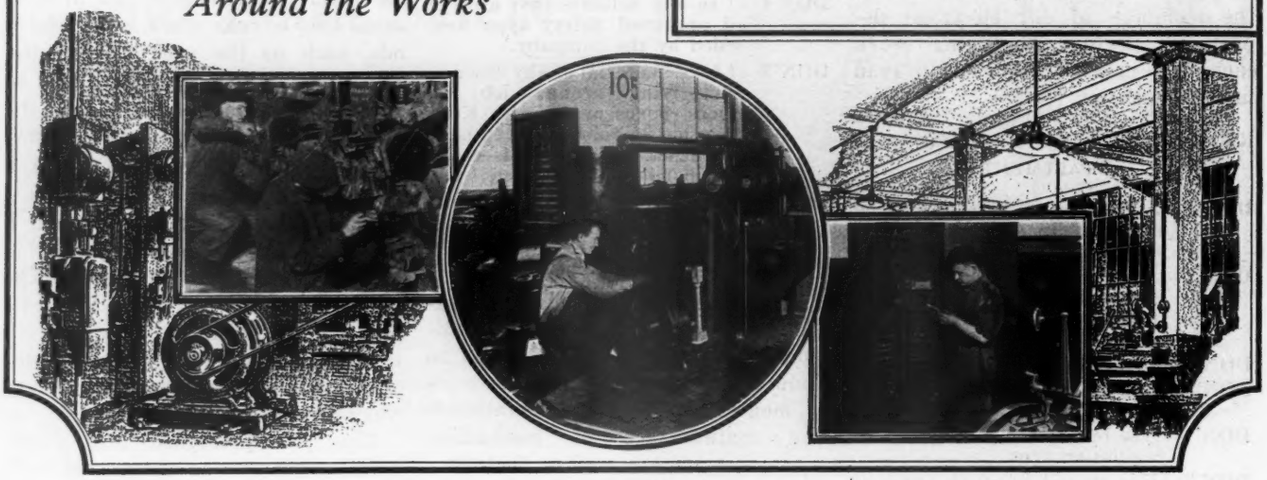
The cost of breaking up this pit by methods other than dynamite was estimated to be well over $1,000. It was successfully broken with about $15 worth of explosives and the time of one driller with a jackhammer air drill and of one blaster, who each worked less than three days. Successive charges of dynamite were placed at the proper points in the concrete and the walls broken down in sections. The shots were so gaged that no damage was done to surrounding buildings.

These two illustrations show the covering of the concrete pit foundation to prevent broken pieces flying about when blasting.

Electrical Service

Around the Works

For this section ideas and practical methods devised to meet particular operating conditions are invited from readers. The items may refer to inspection, overhauling, testing or special installations.



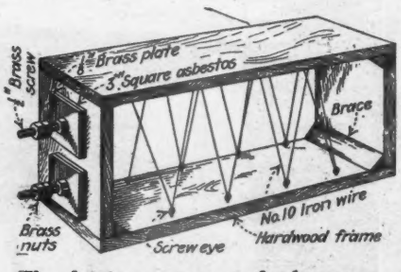
Electric Heaters for Drying Out Large Motor

AT ONE time I served as electrician on a suction dredger whose centrifugal pump was driven by a 750-hp., 2,200-volt, three-phase, wound-rotor motor. Inasmuch as there was very little space between the motor and the other equipment, so that it was very difficult to make repairs, we took the best possible care of it in order to prevent a breakdown. The motor was, of course, in a very damp location and to avoid trouble from this source I made up several electric heaters for drying it out. These heaters were so easily and cheaply made and worked so satisfactorily that a description of them may be interesting.

As will be seen from the illustration the heater consisted of a hardwood frame, well braced at the corners, with loops of No. 10 iron wire supported by two rows of screw eyes in the two sides of the frame. Mica was placed under the screw eyes to keep the wood from charring. The ends of the resistance wire were connected to two terminals in one end of the frame. These terminals consisted of long, ½-in. brass screws, with the heads cut off, which were passed through brass plates ⅛ in. thick and 3 in. square. Two plates were used for each terminal, one on the inside and one on the outside of the frame. Under each plate was a layer of sheet asbestos to protect the wood of the frame.

The brass screws forming the terminal posts were held in place by locknuts on each side. In order to avoid the possibility of grounding, the holes where the screws passed through the wood were made considerably larger than the holes in the brass plates.

Power was delivered to the dredge at 11,000 volts through a submarine cable. Three delta-connected transformers were used on board, giving 2,200 volts. When in use the heaters were kept, for the sake of long life, at a "black heat," which meant that they had to be operated at 440 volts. When it was necessary to use the heaters during a shut-down, one of the transformers was disconnected, leaving the other two connected in open delta so that it was possible to operate the other 2,200-volt motors. The third transformer was then operated at 2,200 volts on the primary side, which gave 440 volts on the secondary for the heaters. Although this may seem like a cumbersome way of securing the proper voltage for the heaters, it was the best that we could do with the equipment available, and the transformers were so arranged that we could make the necessary changes either way in about 10 min.



The heaters were made by supporting loops of No. 10 wire on screw eyes in the two sides of a hardwood frame.

The rotor of the large motor had eight spokes and by turning it so that the spokes came in line with the braces on the end bells six heaters could be placed in the rotor. When the heaters were in place a tarpaulin was thrown over the motor, to dry it out and keep it dry.

San Francisco, Calif. S. H. SAMUELS.

Two Schemes for Controlling Lights From Two Points

THE following comments have been received relative to a short article by P. Justus, which appeared under the above heading on page 99 of the February issue of INDUSTRIAL ENGINEER.—EDITORS.

* * * *

I noticed on page 99 of the February, 1924, issue a cut of hot-line 3-way switches in an article by P. Justus. In view of Rule 24, Section C of the 1920 National Electrical Code and Article 12, Rule 1204, Section A of the 1923 code, which states that, "Three-way switches shall be classed as single-pole switches and shall be so wired that only one pole of the circuit will be carried to either switch," I think there should be a note of explanation regarding this illustration, to the effect that the method of connection shown is not permitted under these rules.

Philadelphia, Pa. C. B. HUMPHREYS.

* * * *

On page 99 of the February issue there was a short article by P. Justus giving two schemes for the hook-up of 3-point switches. I would suggest that before any electrician attempts to install 3-point

switches according to Fig. 2 of that article, he had better consult Section 1204a of the 1923 National Electrical Code. This states that three-way switches shall be classed as single-pole switches and shall be so wired that only one pole of the circuit will be carried to either switch. While the practicability of work installed in accordance with Fig. 2 is all right, it might cause some embarrassment and inconvenience to the electrician installing it, if it has to be passed on by a local electrical inspector. W. C. GRUBB.

Auburn Junction, Ind.

* * * *

On page 99 of INDUSTRIAL ENGINEER for February there are shown two methods of connection for the two-location control of a circuit in which two 3-way switches are used.

It should be noted that the scheme shown in Fig. 2 is prohibited in Rule 1204a of the 1923 National Electrical Code, which specifies that, "Three-way switches shall be classed as single-pole switches and shall be so wired that only one pole of the circuit will be carried to either switch."

Hence, the wiring shown in Fig. 2 should never be employed in installations that are subject to the jurisdiction of electrical departments which follow the National Electrical Code. It is a fact that the wiring method of Fig. 2 has decided advantages for certain conditions and that it may also, under certain conditions, be much more economical of material than that of Fig. 1.

Our feeling here is that the method of Fig. 2 is entirely safe and often justified. However, it has the disadvantage that it reverses the polarity of the socket shells; this conflicts with the 1923 Code ruling which specifies that the shells of all lamp sockets shall be connected to grounded wire. TERRELL CROFT.

Directing Engineer,
Terrell Croft Engineering Co.,
St. Louis, Mo.

Simple Brake for Testing Motors Up to 100-Hp. Rating

A BRAKE which was built in a New Jersey shop for testing motors up to 100-hp. rating, gives very accurate results. Bands of automobile brake lining pressing on a steel pulley give the braking effect. One end of these bands is attached to a wooden scale beam which is balanced by means of iron weights. There are two main 4-in. belts passing up and three-quarters around the pulley, where they are connected to a 2-in. belt, the end of which is fastened by a wire to a small spring scale. The brake lining is of asbestos interwoven with brass or copper wire and stands the heat well. In order to lessen the friction, maple-wood strips are inserted between the band and the pulley. The construction of the brake is shown in the illustration.

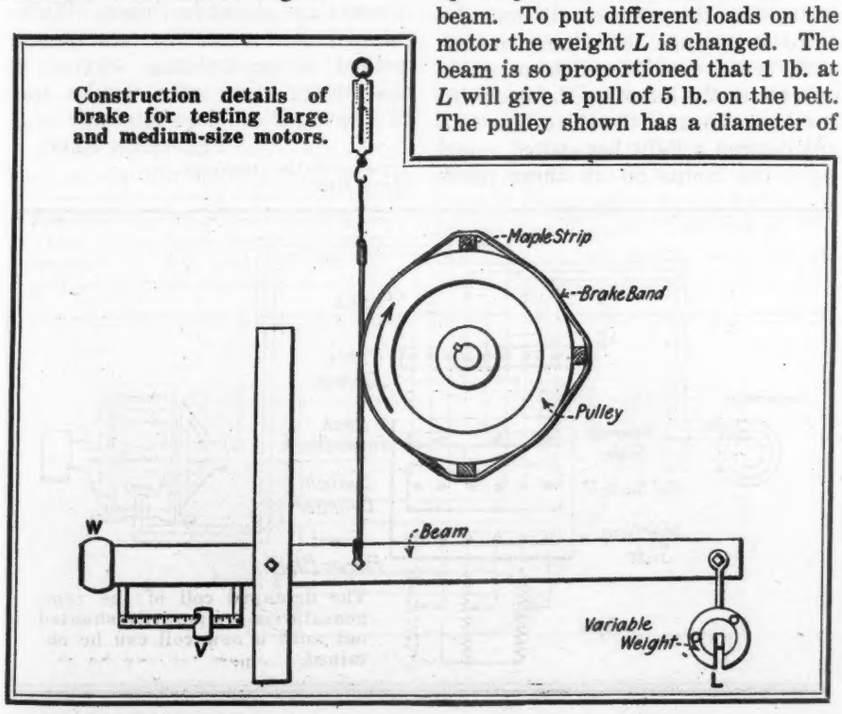
In making a test, after the belt is placed around the pulley the beam is balanced by means of the sliding weight *V*. As the motor is brought up to speed the belt tends to lift the beam. To put different loads on the motor the weight *L* is changed. The beam is so proportioned that 1 lb. at *L* will give a pull of 5 lb. on the belt. The pulley shown has a diameter of 25.2 in. and a 12-in. face. With a pulley of this diameter twice the net pull in pounds multiplied by the revolutions per minute and divided by 10,000 gives the horsepower directly. This pulley may be used for any torque up to 300 lb.-ft. A 12.6-in. pulley is used for measurements up to a torque of 100 lb.-ft. To prevent the pulley overheating it is flanged so that it will hold water during a test.

Care must be taken to prevent the belts jamming around the pulley and tearing loose, with possible serious damage. The best results are obtained when the spring balance pull is about one-tenth of the main belt pull. The net pull, which is used to calculate brake-horsepower, is the pull on the main belt minus the pull on the spring scale.

The bearings of the scale beam are carefully lined and are babbitted. The arm is counter-balanced for its own weight and that of the belts and fittings by weight *W* and the sliding weight *V*. The frame of the brake must be strong enough to stand an upward pull of 1,000 lb.

F. W. GAY.

Chief Tester,
Crocker-Wheeler Company,
Ampere, N. J.



Construction details of brake for testing large and medium-size motors.

Use of Aerial Power Cables in Industrial Plants

AERIAL power cables suspended from a messenger attached to poles or other convenient supports are worthy of careful consideration by the engineer who is responsible for an assured continuous supply of power for operating machinery. Central station companies are gradually coming to use multiple conductor cables in this way and many of the reasons which make this good practice under certain circumstances also apply to large industrial plants.

In the first place open wires for high-voltage circuits are dangerous in congested locations unless very expensive construction is employed. Furthermore, interruptions of service are quite likely to occur with open wires. Aside from the possibility of insulators breaking down and damage from sleet and wind, there is always the liability of some injury by traveling cranes handling an unusually large object or by accidents from entirely unforeseen causes. Strange and unexpected things happen in plants engaged in heavy operations. In a steel plant where the wires were carried on a bracket structure attached to the side of a long building, they were

put out of service every once in a while by an avalanche of snow sliding off the high sloping roof. An aerial cable has been substituted for the open wires and since that time there has been no trouble. Another place where this practice proved beneficial was where a 6,600-volt circuit passed under a coal hoist; in this case the cable was protected by steel wire spirally wound over the lead sheath, similar to a submarine cable.

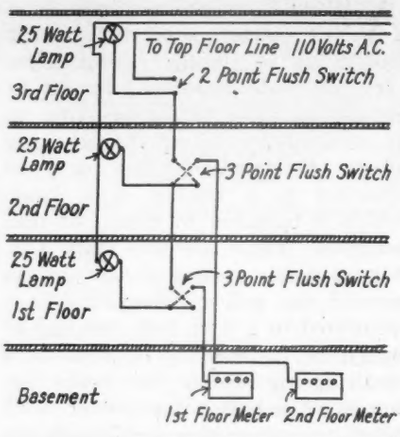
Of course, trouble may be practically eliminated by underground construction and this is employed in many cases but it is expensive and rarely pays except where an entirely new plant is being laid out. In old plants where electrification of the various machines is gradual and piecemeal, the wires are usually attached to poles, roofs, or brackets on the sides of buildings. It not infrequently happens that it is economical to have 6,600-volt circuits for motors of 150 hp. or over or for tying in substations with each other and with the generating station, if there is one, and it is in such cases that it is good practice to use cables. Examples of this method have been observed in steel mills, one of which has nearly two miles of it, as well as in other industrial plants.

The objection may be raised that cable is more expensive than open wires. This is undeniable but it is equally undeniable that the maintenance and depreciation are so much less as to be almost negligible. Practically everyone who has used aerial cable says that there is never any trouble and they forget that they have a cable. But the most important advantage of cable from the practical standpoint is the almost complete assurance of continuous service. In many of the operations in the steel industry, for instance, the value of the material in process of manufacture is so great and the damage to materials and loss in operating efficiency so serious in case of accidental interruptions of power that it pays to spend money on equipment that will eliminate or substantially decrease such troubles. In fact, the attitude of the electrical engineers responsible for the supply of electrical energy is shown by the fact that in the two steel mills mentioned these men regularly install cables designed for double the operating voltage actually used in order to increase the factor of safety. As both of them have expressed it, the comparatively small increase in the first cost of the cable is insignificant when compared to the great importance of delivering energy where and when it is wanted.

New Canaan, Conn. F. A. WESTBROOK.

Method of Wiring for Lights at Stairway

RECENTLY it was necessary to place a small lamp on each rear landing of a three-family tenement building, which was the property of a large manufacturing company, long after the building was completed. Inasmuch as no one family was to bear all the expense of the lighting and there was no special meter for this service, it was decided to arrange the wiring so that each tenant could switch onto his own meter the lamps on the floors below him. Thus, if the third-floor tenant desired a light his switch would light the lamps on all three floors through his meter. Each tenant could thus light his own lamp and all those below him, but none above him.



Arrangement of wiring so that the switch on each floor will light stairway lamps on all floors below, but not above.

The lamps used are only 25-watt rating, but they were wired as described in order to avoid any imposition. In other words whoever switches on, pays.

As will be seen from the illustration the top floor switch was wired to the top floor line for a meter connection, but the first and second floors were wired to their respective meters in the basement, as the lines in the ceilings could not be reached. The wires from the power supply direct to the switches must be on the same side of the circuit.

In reality the job was simple enough and was done by one man in 12 hr. at a cost of about $10.

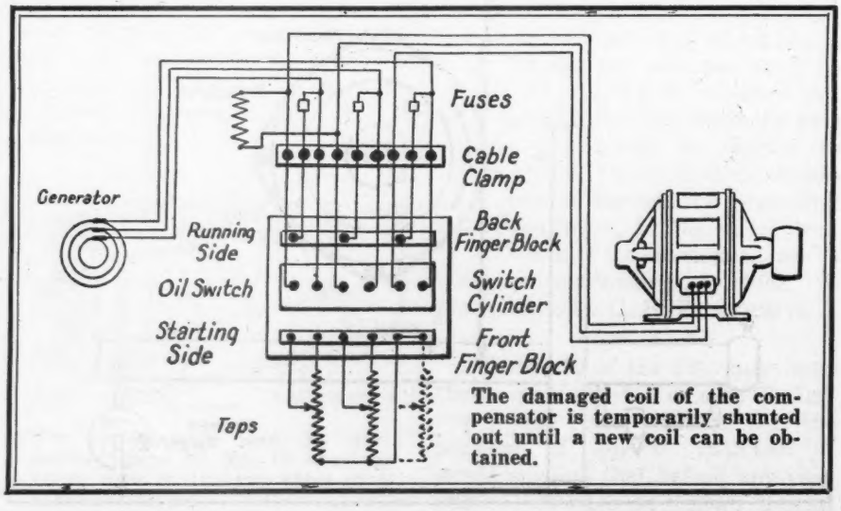
New Britain, Conn. H. S. RICH.

Method of Starting Motors With Damaged Compensator

IN a large industrial plant where a large number of 2,200-volt three-phase induction motors are in use, these have been started with entirely satisfactory results when one coil in the starting compensator was cut out as shown in the accompanying illustration. Spare coils are carried in stock for all of the larger compensators, but occasionally a coil burns out that can not be repaired or for which no replacement is available. When this occurs the damaged coil is disconnected and jumpers are placed as shown. While this is, of course, an emergency method of maintaining service it has always given good results, until a new coil could be obtained.

FREDERICK KRUG.

Comerio Falls, Bayamon, Porto Rico.



The damaged coil of the compensator is temporarily shunted out until a new coil can be obtained.

Mechanical Maintenance of Power Drives

This department will furnish mechanical details of installation, operation and maintenance of equipment in the path of power service from the first mechanical driving element through transmitting equipment to all driven machines.

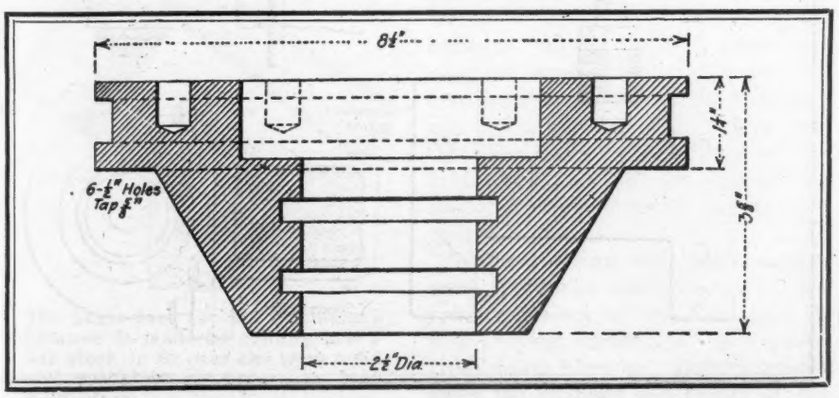
Trouble Reduced by Use of Ball Bearings on Mine Locomotives

OWING to trouble with the brass-lined bearings on the motors of mine locomotives, J. C. Kendall, Hancock, Mich., reports that the Quincy Mining Company (Mich.) found it necessary to replace these bearings with ball bearings. The trouble was due to the armature heating up at times of overload and melting the grease out of the bearings. With no grease in the bearing the shaft would cut the linings out and allow the armature to drop down on the pole pieces. To remedy the trouble it was decided to try ball bearings; so the bearing caps shown in the illustration were built to replace the old caps.

To prevent the ball race from turning on the shaft a jam nut is tightened against it on the pinion end of the shaft. On the commutator end a washer and cap screw perform the same function. The bearing shown in the sketch is for the pinion end, the one for the commutator end being slightly smaller.

Sixteen two-motor locomotives with sixty-four bearings were changed in this manner some time ago, and since then no bearing troubles have been experienced.

Bearing caps like these were used when brass-lined bearings were replaced by ball bearings on the motors of mine locomotives.



Change in Grade of Oil Cause of Bearing Failure

AN INTERESTING case of lubrication trouble came to the writer's attention recently on the motor end of a flywheel motor-generator set, (3,000 hp., 505 r.p.m., 2,300 volts) which supplies the d.c. power to the main drive motor of a reversing blooming mill. During the regular overhauling at the week-end, the oil was drained from one of the bearings of the motor, and the oil basin cleaned out and filled to the proper level with clean oil. On Monday morning the motor-generator set was started as usual and the bearings were given the customary inspection to see that the oil rings were running freely and carrying up oil. About two hours later it was noticed that the bearing in which the oil had been changed, was heating. Preventive measures were taken but before they became effective the babbitt melted and the shaft dropped. The motor was stopped before any damage was done to the rotor.

After considerable trouble the motor shaft was jacked up, the pedestal removed and the bearing taken out. Inspection disclosed no dirt or other foreign matter, either on the shaft or in the oil.

Examination of the oil showed that it was of a somewhat lighter grade than was formerly used. It was found that because of a difference in price an oil made by another manufacturer and which was said to be of the same grade as the original oil, was bought by the purchasing department. The storeroom gave the maintenance man this oil for use on the machine and no mention was made of the change of manufacturer. The trouble encountered proved that the oil was not of the same grade and was not suited to the needs of the bearings on this machine.

A new bearing was put in the motor and the original grade and make of oil was substituted for the oil in question. No further bearing trouble was encountered on this machine. In the writer's opinion changes should never be made in the grade

or make of oil used on important drives until careful tests have shown that the new oil is suited to the service requirements. U. A. J.
Chicago, Ill.

Individual Drive for Swinging Frame Cross-Cut Saw

FOR driving a swinging-frame cross-cut saw, an industrial plant in Connecticut has adopted the method illustrated of mounting the motor directly on the cross-frame of the saw. The motor is served from a wall outlet just back of it, the conductors being coiled to allow swinging of saw. In order to protect the operator from injury the belt is incased by a wooden guard, as shown in the illustration. The motor is controlled by means of a 30-amp. C. R. General Electric push-and-pull switch mounted near the operator.

Mounting the motor on the cross-frame of the saw was a convenient way of obtaining individual drive.

Application of Direct Drive to Drill Press

IN ONE SHOP where the various items of machine shop equipment were driven from a lineshaft, it was desired to avoid the necessity of driving the entire line of shafting and pulleys to operate only the drill press which was, as usual, the most frequently used piece of equipment.

The adoption of direct motor drive was decided upon; after consideration of the possible methods of mounting the motor it was decided to mount the latter in a vertical position, as shown in the illustration. For this purpose a simple form of strap bolt was made to encircle the drill press frame at the back and support a baseplate to which the motor was securely bolted. A direct belt drive to the spindle was then possible, without the use of intermediate pulleys or shaft.

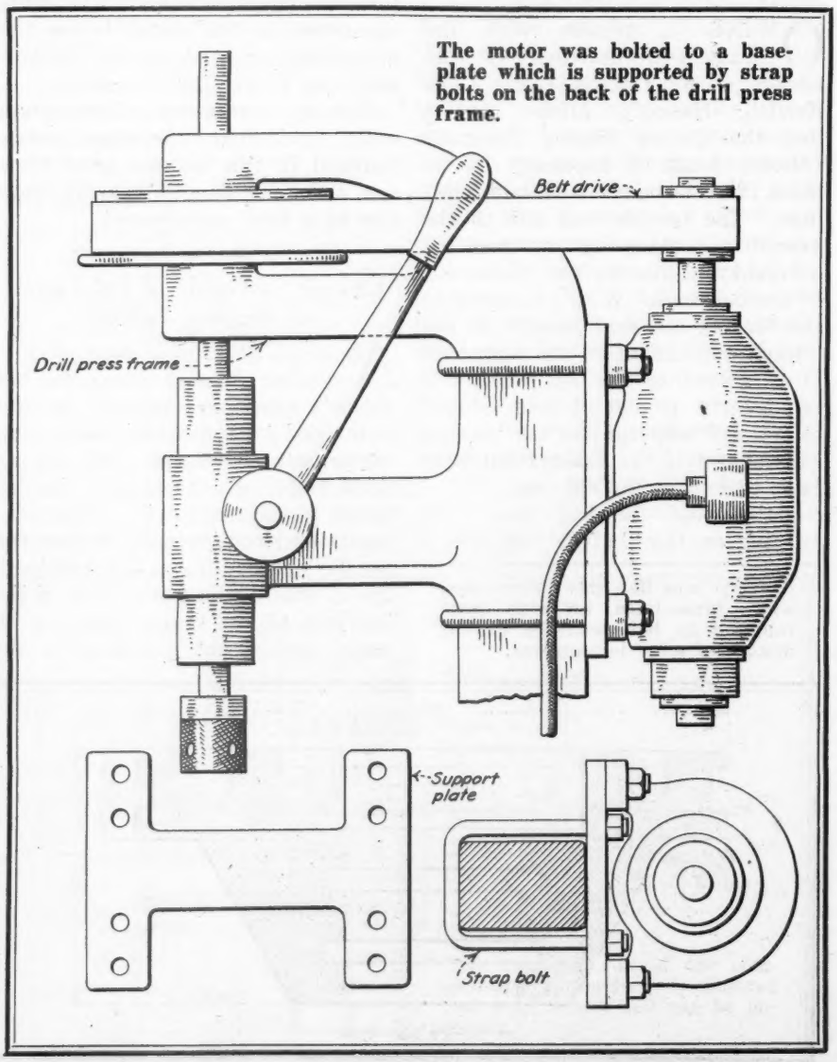
This motor has been operated vertically for more than a year and the installation has proven to be very satisfactory, although there was some apprehension at first that the bearings would not stand up. While it was the original intention to place a small thrust-plate directly under the armature shaft, this has not been found necessary as the interior thrust bearings in the motor are adequate for the weight of the armature. G. A. LUERS.
Washington, D. C.

How an Uneven Belt was Made to Run True

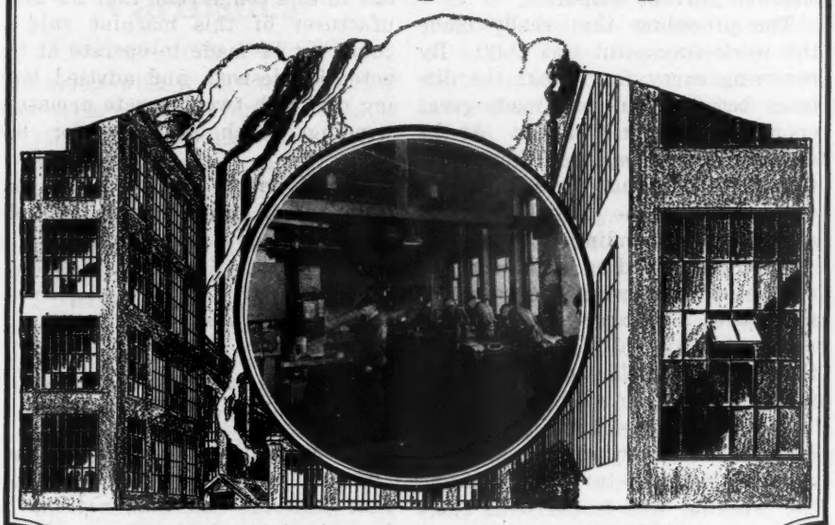
THE defective portion of the driving belt of a high-speed, three-bearing generator was recently removed and replaced by a new piece. When the machine was started, following the repair, the belt persisted in running off to one side, bringing one edge in contact with the outboard-bearing pedestal of the generator. As a result, the edge of the belt became stretched and worn and began to flare out.

The difficulty was overcome by transferring the crown of the pulley from the middle of the pulley face to a point nearer the center bearing. A ring of ⅛-in. holes was drilled around the pulley face at the place it was desired to have the new crown and a strip of rawhide belt lacing riveted in place. After this the belt ran true, as the effect of the new crown was to force the belt to the center of pulley. A. J. DIXON.
St. Louis, Mo.

The motor was bolted to a baseplate which is supported by strap bolts on the back of the drill press frame.



In the Repair Shop

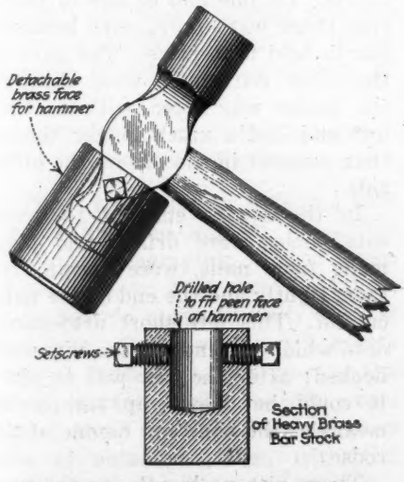


This section is devoted to repair work, large and small. Special attention is given to shop or bench tools and short cuts or improved methods. Contributions are always welcome.

Brass Face for Hammer Reduces Weight of Kit

THE brass hammer is a very useful tool for pounding on parts which would be injured if the ordinary machinist's hammer were used. However, it is one of the heavy tools of the repair kit and if both it and a machinist's hammer must be carried the weight of the kit is considerably increased. The method which was adopted by one repairman to keep down the weight of his kit is shown in the illustration. As will be seen he made the brass face as a detachable part of his hammer.

This was done by drilling a short piece of heavy bar stock for a close fit over the peen head of the hammer; two holes were then drilled and tapped for setscrews to hold it in place.



The brass face for the machinist's hammer is made by drilling heavy bar stock to fit over the peen head and providing set-screws to hold it in place.

When the brass face is attached to the hammer, driving work is accomplished with the same facility that is provided with a solid hammer. When detached the brass face can readily be stowed in the kit without adding any appreciable extra weight.

Washington, D. C. G. A. LUERS.

Two Repair Shop Experiences That Taught Lessons

SOME TIME ago, when making repairs outside of the shop, we were working on an elevator whose reversing switch repeatedly burned out the contacts. On this switch the armature and shunt contacts broke the connection at the same time; the armature contacts had a sharp, snapping spark to them. When the shunt fields were connected across the lines permanently, the armature contacts barely sparked when the machine stopped. We then put the field leads back where they belonged and put a suitable resistance across the field leads to take care of the field discharge and the switch has operated satisfactorily for several years.

When relating my shop experiences, I may as well give one of our prize mistakes in the hope that it will prevent some other repairman from doing likewise. This happened when we changed the throw of the coils on the armature of a Westinghouse interpole motor. The plant first sent in the armature alone to be rewound. The armature had fifty-nine coils and was wound 1-16. This checks out 1-16-31-46-61, or two past the number of coils. Before this, we had always thought that if the throw did not come out even it was better to wind it under rather than over. As 1-15 came out 1-15-29-43-57 we wound it 1-15 without changing the throw of the top lead or the span of the bottoms from the top.

When the armature was put back into service it ran all right under no-load, but sparked and ran hot under load. The entire motor was then sent into the shop and we found that by shifting the brushes we could reduce the sparking but not the heating. We then wound the armature 1-16 and the machine has run fine ever since. Evidently the Westinghouse Company must set their brushes by the throw of the bottom lead. We also found that it does not pay to change the throw of the coils from the factory span.

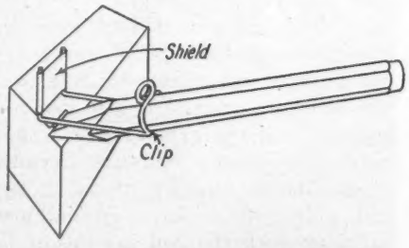
I hope these experiences will be helpful to some of the other readers and would like to get some of theirs.

Peoria, Ill. GEORGE RINGNESS.

Shield for Chisels Keeps Chips From Flying

MANY times when using a chisel we want to keep the chips from flying, when the metal is worth saving or the chips will annoy other workmen or get into electrical equipment. The accompanying drawing shows a shield that can be applied to chisels to keep chips from flying about, save windows and keep workmen from complaining about "the other fellow."

The clip is made of piano or other spring wire formed so as to grip the chisel. The shield is made of thin sheet stock, with the ends curled to slip over the bent-up portion of the clip. The clip can be slipped back and forth on the chisel



A piece of spring wire is bent to form a clip which grips the chisel and supports a thin metal shield.

to get the required distance, and bent to get the proper height of the shield. When grinding the chisel the clip may be slipped back out of the way or removed entirely. By making a fair-sized loop the clip will have sufficient spring to enable it to be used on several sizes of chisels.

Detroit, Mich. NELSON HALL.

Rewinding 44-Volt Generator to Give 1,000 Volts

NOT long ago I received a call from the officer in charge of a government radio station to come out and look over a generator with a view to making some changes in it. I was much elated over the prospect of adding this station to my list of customers, but upon arrival and being shown the machine and the nature of the proposed changes my elation was, for a time, suddenly changed to something else.

The proposed changes involved not only a rewinding job but also a re-designing job, due to the fact that the new voltage was to be many times that for which the machine was designed. At the outset it was apparent that design procedure should be reversed, in that it would be most expedient to make the armature fit in with the fixed field conditions. The original rating was 44 volts, 22.5 amp., 1 kw., and the problem was to convert this machine into a generator that would deliver 0.5 amp. at 1,000 volts. The machine was an old one with a smooth core armature, four poles and 121 commutator bars. The armature core was 6 in. in diameter and about 6 in. long. The commutator was approximately 4½ in. in diameter, making the bars quite small.

After stripping the armature it was sent to the machine shop to have thirty slots milled in it. It came back with the job done perfectly. Work was then started on the commutator—the real seat of all the trouble. Every fourth bar was removed and then three bars were connected together to form one bar. This gave us thirty bars for the new winding. The necessary precaution was taken to reinforce the commutator and brush stud insulation and the armature was then ready for the new winding. Because of the large number of turns per coil (110) we took no special precautions with the coil insulation, as the voltage per turn was low and the coil voltage was also comparatively low. The co-efficient of self-induction was also about as it was with the old winding, due to the lessened current output.

The procedure that really made the work successful was this: By removing every fourth bar the distance between bars was made great enough to prevent flashover. At the same time, the period of commutation was kept about the same as before; in fact the period was less with the new winding.

After the winding had been put on the space between the bars was filled with a mixture of powdered mica, glue and plaster of paris of the right proportion to give it about the same wearing rate as the bars. The winding was then heated and dipped in air-drying varnish, the commutator was turned down and the winding was tested with 3,000 volts alternating current for one minute. The commutator was tested between bars with 350 volts. These tests being passed satisfactorily, the machine was ready to be given the trial run.

The generator was equipped with four brush studs, but only two brushes were in place and I was just a bit dubious about trying it under these conditions, because I realized that with the other brushes in place on the commutator the commutation would be much better. However, it was started up with no load and with a little more than half of the field resistance in and the voltmeter reading about 700, the region between the two brush studs was a solid mass of fire. This was found to be due to two causes: Due care had not been exercised in removing the dust after the brushes had been fitted; also the two brushes were collecting too much current at this voltage. With a clean commutator, and the other brushes in place the machine was started up and the voltmeter showed about 1,200 volts with only an occasional faint spark at the brush tips.

A long message had been prepared, as a test, to be sent to another station and when the machine was connected to the sending apparatus, with less field than was used in the trial run, the pointer of the ammeter connected in the antenna circuit went off the scale. The sending of this message consumed about one hour and fifteen minutes and inasmuch as the generator hummed along with practically no more sparking than on no load, we assumed that it was all right, which assumption has proven to be correct after more than a year of continuous service. It is interesting to recall in this connection, that the manufacturer of this machine said it could not be made to operate at the potential desired, and advised buying one with two separate armature windings, each designed for 600 volts.

All of which goes to show that when one of those "impossible" jobs comes along, it pays to give it a trial. D. L. WAYNE.

Chief Electrician.
Prairie View State College,
Prairie View, Texas.

Easily-Made Hacksaw Frame for Heavy Work

THE ordinary hack-saw frame can be purchased so cheaply that generally there is nothing to be gained by making one yourself. However, the one described below is much stronger than the very cheap types and the knowledge of how it was made may help someone who wishes a stronger hack-saw frame than the ordinary type, or who has the time to make one.

The frame was made by bending to the proper shape a piece of ½-in. wrought-iron pipe about 20 in. in length, the radius of the bends being about 3 in. This left a frame like the letter D, except for the front vertical line, the end pieces being 4 in. or 5 in. in length and the back about 13 in. long.

A ¼-in. hole was drilled through each end of the pipe. In these holes were pieces of steel rod, square in section between the frame and the saw, but threaded on the portion which went through the holes in the frame. On one end of one of these rods there was an ordinary hexagon nut to hold it in place. The part of the other rod which went through the frame was fitted with a wing nut and had a much longer thread than was cut in the one on the other side.

In the square ends of the rods small holes were drilled and pins, made from nails, were driven into them tightly and the end of the nails cut off. This left short projections onto which the ends of the saw were hooked; after the saw was in place it could be drawn up tightly by means of the wing nut on one of the rods.

There was no handle, as the user was expected to guide the saw by means of the vertical ends.

Westfield, N. J. G. H. MCKELWAY.

Applying Insulating Varnishes

(Continued from page 186)

and along with it any oil that may still remain. If the armature is to be stripped, scrubbing with a wire brush as soon as the armature is removed from the washing tank will take off all the old varnish from the surface and render the removal of the coils much easier.

If the gasoline in the washing tank is allowed to stand after use for some time, the dirt and some of the oil will sink to the bottom and can easily be drawn off, leaving the remaining gasoline fit for use once more.

As many additional coats of the baking varnish may be applied as is thought necessary, bearing in mind that for protection against moisture, oil, etc., a perfectly continuous coat is necessary. Cracks or breaks in the continuity will permit oil, moisture and conducting particles to enter the coil, with disastrous results as far as protection against shorts or grounds is concerned. Fibrous insulation, such as cotton, has many stiff hair-like fibres that tend to pierce the varnish film. When they do they act like wicks and tend to draw moisture and oil into the interior of the coil by capillary attraction. These fibres must be completely covered. Because of lack of time and production expense it is not always practicable to apply five or six coats in the manner described above; hence the results desired are approximated by applying as many baked coats as possible and then following with one or more applications of air-drying varnish to obtain the continuity of film.

Application of Brushing and Spraying Method

These air-drying or finishing varnishes may be applied by either brushing or spraying. If the brush is used special care must be taken. It is best to apply liberally at first and then, after squeezing the excess varnish from the brush, go over the whole surface with a thin coat, smoothing it down until a good, even film is obtained. Even with the greatest care, however, some parts are very likely to be overlooked.

It is not wise to depend upon brushing for the entire treatment of coils. It is impossible by this means to force the varnish into the interstices where insulation is most needed. Hence brushing is recommended for cases where surface protection only is required.

The Air Spray.—Spraying is considered preferable to brushing. The work can be done evenly and quickly. It does not, however, insure the complete filling of the coil and hence it is advised only for the finishing applications as an alternative for the brushed coat. It uses a little more varnish that when the hand brush is used, because heavier coats are applied. The expense of application, however, will be no more because of the saving in time and labor required for treatment of a given piece.

The spray is simply an air brush in which compressed air forces the varnish out through a nozzle in a very finely divided state. Much of the solvent is evaporated between the time the varnish leaves the nozzle and the time it strikes the work. Hence it will be found that the varnish film dries much faster than in any other application. In spraying large pieces such as complete stators, by the time the first coat has been completely put on, the surface where the start was made is dry enough for a second application. Thus very thick coats can be built up in a comparatively short time.

Before selecting a sprayer the amount of work to be turned out per day should be determined, as well as the size of the largest piece to be treated. Then consult a reliable manufacturer of varnish air sprayers, giving him at that time the maximum air pressure available in your shop. Nozzles with adjustable size openings are the best, as they may be adapted to the particular kind of varnish used. An air transformer set to remove dirt, moisture and oil from the compressed air, together with the connections and proper exhaust arrangement, should be installed at the time the sprayer is put in. The exhaust equipment consists of a hood connected to the outside air with a suction fan to draw the fumes and vapors away from the room.

When through using the sprayer for the day, it should be thoroughly cleaned, particularly the nozzles, taking care that no partially dried varnish remains to clog the openings. The thinner used for the varnish is entirely suited for this purpose.

Fig. 5—Vacuum pressure impregnation outfit in shop of Atwater-Kent Manufacturing Co., Philadelphia, Pa., as made by the Buffalo Foundry Machine Co., Buffalo, N. Y.

In some shops where no oven is available and where dependence is placed upon the brushing or spraying method, it is the practice to dry the coils by passing an electric current through the windings. This has the advantage that the varnish is dried first inside the coil without the formation of a surface skin. Hence thorough drying is obtained throughout. It is, however, costly and therefore not economical when an oven is available.

Principles of Vacuum-Pressure Impregnating Method

Still another method of applying insulating varnish to coils is by means of vacuum-pressure impregnation. Suitable sets for this purpose can be purchased outright. They consist of a storage tank for the varnish, a pressure tank that can be sealed so that no air can get in or out, and a vacuum pump.

The coils to be treated are placed in the pressure tank and heated to about 220 deg. F. All valves are closed except that leading to the vacuum pump. The pump is started and run slowly for from 1 hr. for small coils to 4 or 5 hr. for those of large cross section. This process removes all occluded air and moisture from the interstices of the coil. That is, it simply takes the place of the preheating of the work in the dipping system.

At the end of this time the heat is reduced to about 70 deg. F. and the best vacuum possible is drawn. The valve to the storage tank is then opened, without breaking the vacuum, and sufficient varnish is drawn into the pressure tank to completely cover the pieces. The valve to the storage tank is then closed and the pump stopped, after which air is let in through the valve at the top until atmospheric pressure is reached. This valve is next closed and the pump started in the opposite direction so as to create a pressure of about 15 lb. This is maintained for from ½ hr. to 5 hr., depending upon the structure of the coils and the viscosity of the material used. Then the valve to the storage tank is opened with the pressure still on but reduced to that just sufficient to force the varnish out of the pressure tank. When the material is all back in the storage tank again, the valve is closed and the coils taken out. They will be found to be well drained but should be allowed to stand for at least an hour at room temperature so as to allow the varnish to partially set. They should then be baked in exactly the same manner as has been described in the dipping and baking method.

In general this method is altogether too expensive in comparison with the results obtained for ordinary use. Simple dipping will produce like results provided that it be remembered that a longer time is required to completely fill the interior of the coils.

The process is, however, the only one that will give satisfactory results when solid compounds are to be used instead of the varnish. These compounds have the advantage that there is no solvent to evaporate and hence they completely fill the coils in the first application. It must be remembered, however, that they resoften under heat and are therefore, unsuited for the treatment of those coils which are subjected to extremely high temperatures, or for the treatment of moving parts where the soft compound is likely to be thrown out by centrifugal force.

The operation of the impregnation set is the same for compounds as for varnish except that the storage tank must be provided with heating coils capable of bringing the compound up to a liquid state. These heating coils should be placed in such a position that the compound is heated from all sides at the same time, rather than applying a very high temperature to the bottom of the tank. If this latter is done the compound at the bottom becomes liquid while that at the top is almost solid and an eruption is quite likely to follow. Also, the temperature of the pressure tank must be maintained throughout the entire operation at that which is required to keep the compound in the liquid state. Generally the pressure required to force the compound into the coil should be at least twice that required when varnish is used.

As the compound is repeatedly heated and cooled the temperature at which it liquifies gradually rises until a point is reached where it is impracticable, if not impossible, to melt it. Before this time arrives it is well to add a compound reducer. This reducer is usually a lower melting point compound having otherwise exactly the same characteristics as the original and mixing perfectly with it. Once the storage tank has been filled with compound it is generally unnecessary to add anything except reducer to replace that which is used in the coils.

The type of apparatus needed in the average shop for the proper application of insulating varnishes and compounds has been outlined briefly together with a description of the general methods to be followed. Whatever method is chosen for applying the varnish, be sure that the equipment is kept clean. Dirty equipment ruins insulation quite as quickly as does a faulty application. Wash your brushes or air spray as soon as you are through using them. Clean the varnish tank and strain the varnish at regular intervals. Remove the accumulation of dried varnish from the bottom of the oven. As in other lines of work, dirt breeds trouble. Keep your varnishing room and apparatus clean.

Goodyear Tire and Rubber Company

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the world. The wholesale value alone of all the many rubber products manufactured in 1923 was upward of one billion dollars. In addition, the industry employs at the present time approximately 200,000 people in 170 manufacturing plants.

After the crude rubber is received it must be washed and worked up several times under heavy rolls to get it into usable form. In one of these rolling or milling processes, the crude rubber is mixed with various compounds, such as sulphur, litharge, coloring matter and other materials. In the manufacture of rubber goods in which cotton cloth is used, the cloth is impregnated with the rubber compound, or "frictioned." These coats are worked together under pressure and vulcanized under heat and pressure, which gives the goods their accustomed appearance. This treatment also sets the frictioned coat and gives the rubber the life and qualities which are required of it.

Automobile tires, one of the most prominent rubber products, are now largely made by automatic machines instead of by hand as was the former practice. This has resulted in the production of a better tire, because a machine can lay the friction-coated fabric or cord much more smoothly and evenly and draw it to the proper tension much better

than can be done by hand. One of the big problems of the industry is the seasonal demand for one of the most important products—automobile tires. To get steady production the year around requires large investments in finished materials.

Lineshafting and Hangers

(*Continued from page 182*)

the shaft, which would in this way cause extra friction in the bearings and an uneven or vibrating drive. If the belt is too tight any bend is pulled straight with every revolution; this results in a heavy power loss. It is not at all uncommon to find shafts which are bent enough so that it may be noticed by the eye as the lineshaft is in slow operation during the starting or stopping period.

Post hangers are used commonly to fasten shafting to posts or walls. These are made rigid and with two- or four-point adjustments. Where it is necessary to get the extension, as is necessary on a wall to permit the use of pulleys, extension arms are used. Rigid post hangers or boxes give but little opportunity for adjustment. Where adjustment and realignment are so difficult there is more excuse for neglecting misalignment. Post hangers are not used as much today as formerly due to the changes in modern building construction. With steel frame or trussed buildings the hangers are mounted on I-beams attached in turn to the steel trusses. Modern concrete buildings set special anchorages in the concrete ceiling to support shafting or other loads.

Pillow blocks are more commonly used on large shafts or in severe work. Here the cap of the bearing is usually held down with four cap screws and is much more rigid than in a four-point, adjustable shaft hanger where the bearing is held simply by the ends of four bolts. Sometimes on heavy-duty shafts pillow blocks are used on brackets as post hangers. Where the service is severe, and generally on shafting larger than 4 15/16 in., special sling hangers with pillow blocks on the wedge adjusting base plates are used to suspend shaftings. Heavy floor stands with adjustable pillow blocks are used in similar floor service. Whenever possible pillow blocks are mounted on concrete foundations when used for heavy service.

Pressed steel shaft hangers are being used quite extensively in ordinary industrial lineshaft applications. They are not generally used in heavy power service or in the larger sizes. Practically all are made with four-point adjustment.

A later article will take up a discussion of the various types of bearings used in lineshaft operation.

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Frequency Changes in A. C. Windings

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60-cycle winding, the original 25-cycle turns and wire size could be used. The only changes required would be in the coil pitch. In this case all new coils would have to be made up, as it is hardly ever possible to spring coils back the amount required in this change.

In any change the final calculations can vary at least 10 per cent higher or lower from the actual required amounts without any serious results in the operation of the changed windings.

When the use of these tables is thoroughly understood they will save considerable time and worry when it is desired to make any of the changes that have been described.

Changes in Rotors.—The statements thus far in this article cover the stator winding, but when changing the frequency, the rotor is also affected. If the rotor is of the squirrel-cage type, the resistance of the end rings will have to be altered. When the frequency is raised the resistance of both end rings must be increased. If the starting and full-load torques are to remain the same, on a 25 to 60 cycle change, the cross section of each end ring should be reduced one-half. If this is not done, the motor will pull an excessive current while starting and will also take a higher full-load current.

Therefore, when increasing the frequency, increase the resistance of the rotor end rings by decreasing the cross section of each ring according to the following proportional relation: A is to B as D is to C, from which the following formula is derived: $A \div B$ equals $D \div C$ or $B = AC \div D$, where A equals the area in square inches of each end ring at the old frequency, B the required area at the new frequency, C the old number of cycles and D the new number of cycles.

With a small cycle change, such as 40 to 60, 25 to 40, etc., the rotor can be put in a lathe and a cut taken off each end ring and with a 25 to 60 cycle change reducing the area of each ring one-half will be sufficient. When reducing the frequency, say, from 60 to 25 cycles, the resistance of the rotor end rings must be decreased, or the cross sectional area in square inches increased as indicated by the above formula, the letters having the same meaning. With a small frequency change such as 60 to 40, 40 to 25, etc., brazing the rotor bars to each end ring will decrease the resistance a sufficient amount.

The above changes are important and should be made regardless of any change made in the number of poles in the stator winding. The above statements are based on the fact that the resistance of the rotor end-rings on a 25-cycle motor is lower than that of the rings on a corresponding 60-cycle motor; conversely a 60-cycle motor will have higher resistance rings than those of a corresponding 25-cycle motor.

When the rotor is of the slip-ring type, and a change in the number of poles is made in the stator winding, a corresponding change must also be made in the rotor winding. That is, the rotor winding must be considered in the same light as the stator winding and the coil pitch checked. Then if a change is required, vary the turns per coil and size of wire according to the tables governing the stator change.

Trade Literature
You Should Know About

Copies of literature which is described on this page can be obtained by writing to the manufacturer whose name and address are mentioned. It is always advisable to state the name and number of bulletin or catalog desired, as given in these columns.

Midwest Steel and Supply Company, Inc., 28 West Forty-Fourth Street, New York, N. Y.—The 54-page architects' and engineers' data book on "Midwest Steel Sections" shows numerous methods and types of anchorage for erecting and supporting overhead shafting layouts, piping, cables, machinery, monorails, car tracks and various other equipment, either overhead, on the wall or the floor. Particular attention is given to types of anchorage and methods of installations in concrete buildings especially toward making provision for such anchorage in the construction of the building.

National Electric Manufacturing Company, Inc., 651 Chatfield - Woods Building, Pittsburgh, Pa.—Folders describe the "Syntron" electric hammer and illustrate its use for drilling or chipping. This is of about the size and appearance of an electric drill and will strike 60 hammer blows a second. The hammer head is driven back and forth between two coil magnets. This can be used for drilling or chipping and is portable so that it can be carried to any part of the plant. It is especially applicable for miscellaneous drilling in concrete such as is necessary for erecting machinery or for other miscellaneous maintenance and erection work.

U. S. Galvanizing and Plating Equipment Corporation, 32 Stockton Street, Brooklyn, N. Y.—A folder describes the U. S. moving electrode plating apparatus for plating with nickel, brass, copper, tin, silver, gold or zinc. This not only gives a description of the equipment and the advantages claimed for it, but also indicates the variety of work done.

Detroit Torch and Manufacturing Company, Detroit, Mich.—A folder illustrates and describes the various Detroit portable torches and fire pots.

Crown Die and Tool Company, 555 West Monroe Street, Chicago, Ill. —A 16-page catalog covers Crown pipe stocks, dies, cutters, reamers, portable pipe benches, and portable and bench vises. Diagonally serrated pipe-cutter wheels are claimed to be easy cutting and have a long life. These are made to fit any standard size of pipe cutters.

Warren Manufacturing Company, Natick, Mass.—A folder describes the Acme portable lamp and floor stand which has an adjustable arm so that it can cover any point within an 8-ft. circle and reach to a height of 7 ft.

Electric Tester Manufacturing and Sales Corporation, East Sixth and Stark Streets, Portland, Ore.—A folder describes the Universal fuse and circuit tester for testing alternating- or direct-current circuits of 110 to 600 volts. This tester is claimed to be amateur-proof and is compact, as it weighs only 8 ounces. The lamp is enclosed so that there is no danger of glass flying in case of breakage.

Weston Electrical Instrument Company, 4 Weston Avenue, Newark, N. J.—A 24-page booklet entitled "Electrical Savings in Industry" shows how Weston electrical measuring instruments may be used to obtain industrial economies. The interesting part of this booklet is that it shows actual economies made and how they were located. Some of the economies were in power distribution; others in the use of motors, in proper arrangement of motors, in a study of new installation, in investigations into equipment reliability and into the use of light, and in making a power survey.

Terkelsen Machine Company, 346 A Street, Boston, Mass.—A folder describes the Terkelsen machine for wrapping coils with a continuous protective strip.

The Ransome and Randolph Company, Industrial Division, Post Office Box 905, Toledo, Ohio.—A folder describes the special mica milling cutters and undercutter.

Wilboken Manufacturing Company, Milwaukee, Wis.—Catalog 23 gives the line of Wilboken electric pressure switches for use in controlling the operation of air compressors, pressure release valves with wiring diagrams, or switches to be used in connection with pumps where the equipment is cut in or cut out by floats or pressures, and other types of control switches.

The Imperial Brass Manufacturing Company, 1200 West Harrison Street, Chicago, Ill.—Folder 177 B covers the Imperial welding and cutting equipment which uses the oxyacetylene process. This includes also acetylene generators.

Trico Fuse Manufacturing Company, Milwaukee, Wis.—A folder entitled "When Buying a Fuse Look at the Inside" describes the construction and other special features of the Trico renewable cartridge fuse which is powder filled.

Whiting Corporation, Harvey, Ill.—Two recent folders entitled, "Bucket-Handling Cranes" and "Whiting Power House Cranes," illustrate and describe this equipment in use in the two fields indicated by the titles.

William W. Nugent and Company, Inc., 410-412 North Hermitage Avenue, Chicago, Ill.—Bulletin 6 describes the Nugent shaft oiler, a special oil can which enables the shop man to oil from the floor. This eliminates the necessity of using ladders for such work, and also eliminates the resultant accident hazard.

Chas. A. Schieren Company, 30-38 Ferry Street, New York, N. Y.—A series of bulletins entitled "Quality Facts About Belting" in looseleaf form will be distributed each month. Those requesting to be placed on the mailing list for this series will receive a binder for filing bulletins as issued each month. The first of the series on "The Buying Guide" discusses: The economy of good belting, its relation to production, the buying problem, specifications—their true values, and the real bases for selection.

Morris Electric Products Company, 101 Fourth Street, Peoria, Ill.—A recent folder describes the Havens universal lamp. This is a portable unit provided with five or twenty feet of extension cord and is provided with a wire guard and rotating reflector on a flexible gooseneck attached to a special grip clamp so that this portable lamp can be clamped on the work and the light easily directed over a wide range even in close quarters. This lamp combines portability and control of the direction of light close to the work in a small unit that can be carried in an electrician's or maintenance man's trouble outfit.

The Brown Hoisting Machinery Company, Cleveland, Ohio—Booklet 10 entitled "Man-Power Multiplied" describes the Brownhoist No. 2, locomotive cranes and shows how they reduce handling costs in eleven different industries. These cranes are mounted on either "creeper" trucks or on four- or eight-wheel railroad trucks and may be used with a bucket, magnet or with a special gripping device for handling miscellaneous material.

Efficiency Refillable Plug Company, 43 North Market Street, Palestine, Ohio—A folder describes a new refillable plug fuse which is made in capacities of 6, 10, 15, 20 and 30 amp. and 125 volts. Other literature describes the types of cartridge fuses manufactured by this company.

The F. V. Edwards Company, Noblesville, Ind.—Catalog C describes the line of "Never-Slip" friction clutches and couplings. These embody a special V-clamping device.

T. J. Tagliabue Manufacturing Company, 18-88 Thirty-third Street, Brooklyn, N. Y.—Catalog 904 covers the entire TAG line of industrial thermometers, automatic controllers, recording and dial indicating thermometers, vacuum gages, gas analysis recorders, oil testing instruments, hydrometers, laboratory thermometers and other products.

Condit Electrical Manufacturing Company, South Boston, Mass.—Bulletin No. 429-3 describes the Condit manhole oil switches, type M-5 and M-6, of a maximum rating of 300 amp. and 4,500 volts. These single-throw, two-, three- or four-pole switches are provided with a detachable supporting bracket and oil well to facilitate the treatment and testing of oil.

Delaware Hard Fibre Company, Wilmington, Del.—A folder describes "Egyptian" fibre, gives its characteristics, both physical and electrical, stock sizes, and suggestions on methods of working it.